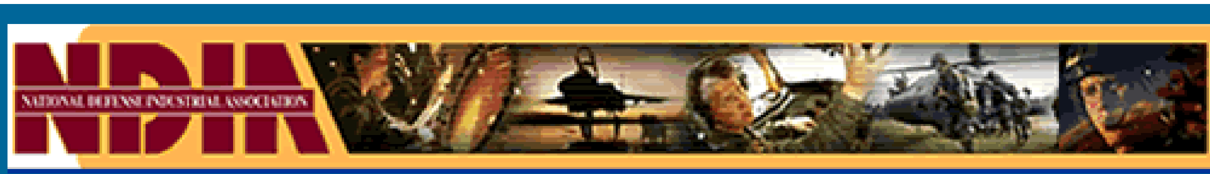

2007 Joint Service Power Expo

"Power & Energy Independence for Warfighters"

24 – 26 April 2007

San Diego, CA

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TUESDAY, 24 APRIL 2007

OIF – Stories From the Field – Lessons Learned

WEDNESDAY, 25 APRIL 2007

Workshop Battery Technical Manuals and Milspecs, *Ms Susan Waggoner*
- Solar Power Adapters and Deployable and Renewable Alternative Energy Module, *Major David Morris*
- Tactical Power Systems, *Mr. Tom Lederle*
- Self-Generated Field Power Sources, *Mr. Albert Hartman*

THURSDAY, 26 APRIL 2007

- USMC Family of Environmental Control Equipment, *Major David C. Morris*
- Integrated Trailer-ECU-Generator (ITEG), *Major David C. Morris*
- Solving power supply obsolescence, reliability, and power density issues by advances in power electronics technology, *Mr. Richard Sidley*
- Advances in Chemical Hydride Based PEM Fuel Cells for Portable Power Applications, *Shailesh Shah*
- Advances in Chemical Hydride Based PEM Fuel Cells for Portable Power Applications, *Mr. Andy Wallace*
    - Video *Customer Broadcast*
    - Video *Customer UAV*
    - Video *Customer UGV*
- Data Systems for Enhanced Power and Energy Management, *Mr. John Adams*
- Back up Slides - Data Systems for Enhanced Power and Energy Management, Part 2 *Mr. John Adams*
- Portable Power Sources: One Size Fits None – Protonex Technology Corp, *Mr. Phil Robinson*
- Solid Oxide Fuel Cell Power Systems for Small UAV's, *Mr. Timothy LaBreche*
    - Video *UAV Fuel Cell Flight with Timer*
    - Video *11.5 Hr Ground Test with Time*r
    - Video *BOP Buner UAV*
    - Video *Short Crash Loop*
- Portable, JP-8 fueled battery charger for remote operation and portable solid oxide fuel cell systems, *Ms. Christine Martin*

Monday, April 23, 2007

1:00 p.m. - 5:00 p.m.	**Exhibitor Move-in**

Tuesday, April 24, 2007

7:30 a.m. - 8:30 a.m.	**Continental Breakfast**	
8:30:00 a.m. - 9:30 a.m.	**General Session**	
	Admin Remarks	
	Color Guard	
	Welcoming Address	
	Keynote Speaker	**Major General Stephen T. Johnson**
9:30 a.m. - 5:00 p.m.	**Exhibit Hall Open**	
9:30 a.m. - 10:00 a.m.	**BREAK in Exhibit Hall**	
10:00 a.m. - 11:30 a.m.	**OIF - Stories from the Field - Lessons Learned**	
	LtCol K. Jansen	**A Few OIF Power Observations**
	Ken Zemach	**Battlefield Power for the Warfighter Lessons for the Development Community**
	GySgt R.L. Gardner	**9th COMM BN ENGINEERS OIF LESSONS LEARNED**
	GySgt G.V. Yanez	**OIF 5-7 Commercial Power Generators**
11:30 a.m. - 1:30 p.m.	**LUNCH**	
1:30 p.m. - 3:00 p.m.	**Session 1 - Chair: Joanne Martin joanne.martin@usmc.mil**	**Session 2 - Chair: Don Brockel Donald.Brockel@us.army.mil**
	Doing Business with the Government - Yvonne Hicks & Shekela Hutchinson	**Determining the Right Type and Quantity of a Power Source - US Army CERDEC/LRC, Don Brockel (#4931)**
	Doing Business with the Marine Corps - Shekela Hutchinson	**Future of US Navy Electromotive Power Logistics - NAVAIR, LCDR Davis Spurlock (#4841)**
	Marine Corps Systems Command Purchasing & Evaluation of Power Items - Michael Gallagher	**Planning and Decision Support for Enhanced Power and Energy Management - MTS Technologies, Inc., Stephen Sullivan (#4823)**
3:00 p.m. - 3:45 p.m.	**BREAK in Exhibit Hall**	
3:45 p.m. - 5:15 p.m.	**Session 3 - Chair: Mike Brundage Michael.Brundage1@us.army.mil**	**Session 4 - Chair: Bob McKenzie robert.h.mckenzie@usmc.mil**
	Future Trends and Thrust for Army Manportable Power Sources - CERDEC, Mike Brundage (#4930)	**Marine Corps Mobile Electric Power Distribution System Replacement - USMC, MSgt Fred McCue (#4649)**
	Advancements in Navy and USMC Power Systems - NSWC Carderock, Justin Govar (#4902)	**The Case for Smart/Safe Power Management and Distribution for the Military - Custom Manufacturing & Engineering (CME), Rick Silva (#4835 & 4839)**
	DoD Battery Technical Working Group - US Army roadmaps and databases CERDEC, Marc Gietter (#4929)	**Fuel reduction solutions for deployment of mobile electric power systems - Oerlikon Contraves, Philippe Bisaillon Eng. MEM (#4805)**
6:00 p.m. - 8:00 p.m.	**Conference Reception in Exhibit Hall**	

Wednesday, April 25, 2007

Time			
7:00 a.m. - 5:30 p.m.	Exhibit Hall Open		
7:00 a.m. - 8:00 a.m.	Continental Breakfast in Exhibit Hall		
8:00 a.m. - 9:30 a.m.	Session 5 - Chair: Maj Daniels regina.daniels@us.army.mil	Session 6 - Chair: Julie Banner julie.banner@navy.mil	Session 7 - Chair: Mike Bissonnette mbissonnette@mkisystems.com
	Mobile Electric Power for Today and Tomorrow - DoD Project Manager Mobile Electric Power, Paul Richard (#4829)	Ultralast Chinese Li/FeS2 Cells - David Hale Associates, Inc., Robert Byrnes Sr. (#4860) High Voltage Systems: Do's and Don'ts - Naval Surface Warfare Center Crane, Susan Waggoner (#4918) Large-sized Li-ion battery module for hybrid powered energy systems - GS Yuasa Corp., Koichi Nishiyama (#4690)	MILITARY TRAINING Communications power sources & vehicle battery maintenance
9:30 a.m. - 10:15 a.m.	BREAK in Exhibit Hall		
10:15 a.m. - 11:45 a.m.	Session 8 - Chair: Maj Daniels regina.daniels@us.army.mil	Session 9 - Chair: Don Brockel Donald.Brockel@us.army.mil	Session 10 - John O'Donnell john.h.odonnell@usmc.mil
	Mobile Electric Power Lessons Learned in the Global War on Terror - USMC, Robert McKenzie III (#4647) Case Study - Reducing Premature Failure of Parts with Interactive Virtual Training for Generator Operators - NGRAIN Corp., Erik Kaas (#4840) Lightweight 2-kW Generator with Electric Start and Voltage Regulation - Mainstream Engineering Corp., Gregory Cole (#4884)	Servicing Hawker Vehicle Batteries with Standard Battery Charging and Test Equipment - US Army, TARDEC, Fred Krestik (#4672) Battery Maintenance and Management - Pulsetech Products Corp., Mark Abelson (#4818) Hybrid Li-ion/VRLA Battery for Silent Watch - Modular Energy Devices, Stephen Eaves (#4668)	Testing of COTS/NDI products (Joint presentation) (#4882)
11:45 a.m. - 1:45 p.m.	LUNCH Speaker - Hon. Philip E. Coyle III		
1:45 p.m. - 3:15 p.m.	Session 11 - Chair: Mike Gallagher michael.a.gallagher@usmc.mil	Session 12 - Chair: Marc Gietter marc.d.gietter@us.army.mil	Session 13 - Chair: CWO5 Good pamela.good@usmc.mil
	DOD Efforts in On-Board Vehicle Power (Joint presentation) (#4639)	Research and Development, GEN4 Zinc Air Battery Technology - Electric Fuel Battery Corp., Darrel Morris (#4830) Flexible Hybrid Power Architecture and Evaluation of Multiple Sources Under Load - US Air Force Research Labs, Lt Joshua Johnson (#4837) Power Surety for the Long War - US Army, Rapid Equipping Force Power Surety Branch, Daniel Nolan III (#4662)	MILITARY TRAINING Generators & AUTODISE
3;15 p.m. - 4:00 p.m.	BREAK in Exhibit Hall		
4:00 p.m. - 5:30 p.m.	Session 14 - Chair: Mike Gallagher michael.a.gallagher@usmc.mil	Session 15 - Chair: Sue Waggoner susan.waggoner@navy.mil	Session 16 - Chair: Jonathan Hernandez jhernandez@fbiacademy.edu
	Oshkosh Truck's electric drive approach to mobile power platforms - Oshkosh Truck Corp., Nader Nasr (#4822) 30 kW On-Board Vehicle Power for the HMMWV - ePower LLC, William Henrickson (#4700)	Workshop - Battery Documents Navy Aircraft and Army C/E - US Navy & US Army, Susan Waggoner & Pat Lyman (#4917)	Solar Power Adapters and Deployable and Renewable Energy Alternative Module - Marine Corps Systems Comand, Maj David Morris, (#4673 & 4686) Need for Tactical Off-Grid Solar Power System - NEST Energy Systems, Tom Lederle (#4940)

		Self-Generated Field Power Sources - High Tide, Albert Hartman (#4807)

Thursday, April 26, 2007

7:00 a.m. - 12:00 p.m. Exhibit Hall Open

7:00 a.m. - 8:00 a.m. Continental Breakfast in Exhibit Hall

8:00 a.m. - 9:30 a.m.

Session 17 - Chair: Maj Daniels regina.daniels@us.army.mil	Session 18 - Chair: Jonathan Hernandez jhernandez@fbiacademy.edu
The Family of Environmental Control Equipment - Marine Corps Systems Command, MSgt Teresa Terry (#4689)	Moving Forward with Fuel Cells: Army CERDEC Development & Demonstration Progress - US Army, CERDEC, Elizabeth Bostic (#4684)
Integrated Trailer, Environmental Control Unit, and Generator (ITEG) - Marine Corps Systems Command, Maj David Morris (#4674)	XX25 Reformed Methanol Fuel Cell for Portable Power Applications - UltraCell Corp., Ian Kaye (#4755)
Solving power supply obsolescence, reliability, and power density issues by advances in power electronics technology. - Custom Manufacturing & Engineering, Richard Sidley (#4833)	Advances in Chemical Hydride Based PEM Fuel Cells for Portable Power Applications - Millennium Cell Inc., Shailesh Shah (#4877)

9:30 a.m. - 10:15 a.m. BREAK in Exhibit Hall

10:15 a.m. - 12:00 p.m.

Session 19 - Chair: Sue Waggoner susan.waggoner@navy.mil	Session 20 - Chair: Jonathan Hernandez jhernandez@fbiacademy.edu
Data Systems for Enhanced Power and Energy Management - MTS Technologies, Inc., Zachary P. Hubbard (#4826)	Durability and Performance issues of PEM Fuel Cell Systems for Portable Applications - Hampton University, Dr. Amir Hoshang Chegini (#4685)
Powering the Mobile Warfighter: One Size Fits None - Protonex Technology Corp., Phil Robinson (#4832)	Solid Oxide Fuel Cell Power Systems for Small UAVs - Adaptive Materials, Inc., Brad Clawson (#4838)
The Next Level of Intelligent Power Management & Distribution - Energy Technologies, Inc., Tim Lowe (#4836)	Military 3 kW Jet-Fueled Tactical Fuel Cell Generator - IdaTech, LLC, Eric Simpkins (#4706)
	Portable, JP-8 fueled battery charger for remote operation and portable solid oxide fuel cell systems - Mesoscopic Devices, LLC, Christine Martin & Dr Jerry Martin (#4709 & 4710)

12:00 p.m. Conference Adjourns

12:00 p.m. - 4:00 p.m. Exhibitor Move-out

Battlefield Power for the Warfighter

Lessons for the Development Community

Ken Zemach, Ph.D.
Lion Cells, Inc.
April 2007

SF soldiers in theater ripping apart dozens of MBITR boxes to run them from BA-5590s

Actual operational power supply rigged by soldiers to run $500,000 thermal sight in theater

BLUF

2 years of developing, deploying, and supporting technology in OIF and OEF

- 20% of successful technology deployment is the technology… 80% is logistics (materials, repair, training, support)
- Power is a large part of the logistics nightmare for many items… avoid proprietary solutions whenever possible

Proprietary Batteries: Resupply/Charge

Cooling Vest for Mounted Operations

Viable technology solution but used proprietary battery:

- Field use impared by battery choice
- Reduced value for Warfighter, military, manufacturer

Correct solution:

- BB-2557 and/or BB-2590
- More utility, lower initial cost, lower long term cost, countless substitutes

Proprietary Batteries: Logistics

ECM Device for Critical Application

Uses Proprietary LiIon batteries → System not upgraded to BB-2590s (easy for this system) → Battery pallet lost in shipment… → …for over two months… → Critical equipment unusable → Logistics will continue to be a problem

Proprietary Batteries: Support

Robot

Proprietary battery problems → Unit cold calls manufacturer → Manufacturer calls us, we contact unit

Travel from Baghdad to Mosul (2 weeks) → Replace/update batteries (2 days) → Travel back (3 days)

…three days after returning to Baghdad…

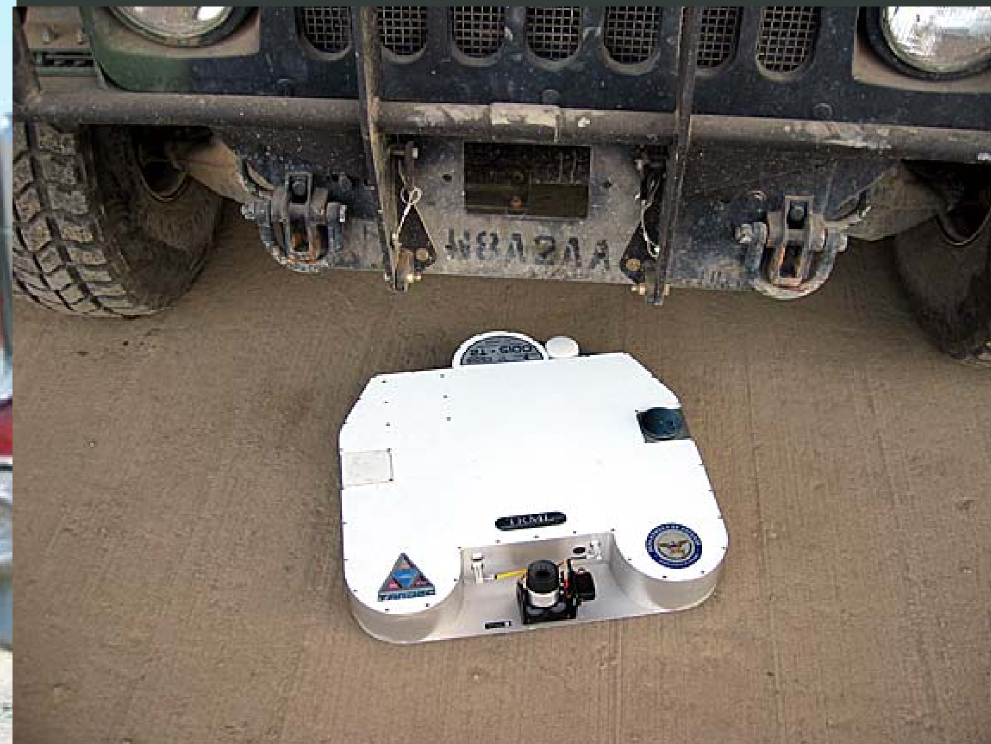
…unit calls: CHARGER DIED → Move charger through LNOs (2 weeks)

Total Time ~ Six Weeks to support due to proprietary power system

Good News: Use the "Standards"

UAV uses standard mil batteries, HMMWV, and/or other sources to run both OCU and recharge lightweight aircraft batteries… best that could be done

Good News: Use the "Standards"



Both these robots run directly off of BB-390/2590 standard military batteries, saving battery and charger logistical nightmares.

Good News: Use the “Standards”

Unique split-body robot for rough terrain under vehicle inspection uses military standard BB-2847 batteries and military standard chargers.

Good News: Use the “Standards”

Run anything COTS from an x90

COTS:

- Cell phones
- Sat phones
- PDAs
- AA chargers
- Laptops
- Camcorders
- DVRs
- LCD monitors
- Surveillance cameras
- Loudspeakers
- Spotlights
- Dremel tool
- Etc.

Good News: Use the "Standards"

LRAS3: Developed for Mounted Units

No AC power supply was ever envisioned to be required in the initial fielding….

LRAS3: Developed for Mounted Units

…so soldiers were hacking together field expedient solutions. Left: HMMWV taken off line to run sight. Right: field rigged power supply. This is not the way!

Two proposed solution approaches for the LRAS3…
Question: which approach is right?

NEITHER

COTS Approach

- UK marine manufacturer
- $2,700 each
- 1 month lead time

vs.

Military Solution

- US military manufacturer
- 9 -12 month lead time
- $250k NRE
- $5k+ each
- Meets strict equipment specs

Good News: Use the "Standards"

SSG D.W. of the 1/506th INF REGT wins with:

Moving to a "standard" 24V Power Supply:

- **Saved 9+ months of R&D**
- **Saved over $250k in NRE for development**
- **Saved over $800k in power supply costs**
- **Avoided logistics/support issues for new custom equipment**

Solar Battery Charging + UPS

Problem: what's the best way to power long term, remote sensors in theater?

- Lots of BA-5590s in parallel
- Several BA-8180s (Zn-Air) in parallel
- Solar UPS… Yes! (self operating, etc); modified military standard SP-4 to get there easily




Product Design and Fielding Issues

Why manufacturers should standardize and/or have the right adapters

- **It CAN be done, and it's not that hard.**
  - **Examples: MARCbot, ODIS, Raven, LRAS3**
- **For manufacturers:**
  - **Reduces time to market, battlefield**
  - **Increases military acceptance**
  - **? Reduces product cost ?**
- **For Military:**
  - **Increases standardization (a good thing)**
  - **Reduces logistics and support issues (<u>HUGE</u>)**
- **Manufacturers (military and consumer) need:**
  - **Directive AND understanding why**
  - **Help with how: recommended options, dimensions, sources, connectors, DC-DC converters, suppliers, etc.**

Most power problems encountered in theater are <u>OUR FAULT</u> (incompatible / proprietary batteries, connectors, cables, etc), *<u>not</u>* because of the operational scenario.

Contact Info

Ken Zemach

Email: kzemach@alum.mit.edu

Useful Website: www.warfightersolutions.com

Export Power Developments

2007 Joint Service Power Expo

25 April 2007

Presenter: **Tom Trzaska**
Manager, Advanced Programs

General Dynamics Land Systems
Muskegon Technical Center
604 Seminole Rd.
Muskegon, Michigan 49441
trzaskat@gdls.com
231.780.5815

GENERAL DYNAMICS
Land Systems

Agenda

- Background
- Technical Objectives
- System Design
- Performance Testing
- Durability Testing
- Future Developments

Background

- GDLS and Magnet Motor GmbH Collaboration
- Robust Power Electronics Solutions
  - Electric Drive
  - Power Conditioning
  - Power Generation
- High Power Densities
  - Inverters to 13.8 kW/l
  - Bi-Directional DC/DC to 6 kW/l

Power Generation and Management Experience

30 kW Export Power Unit

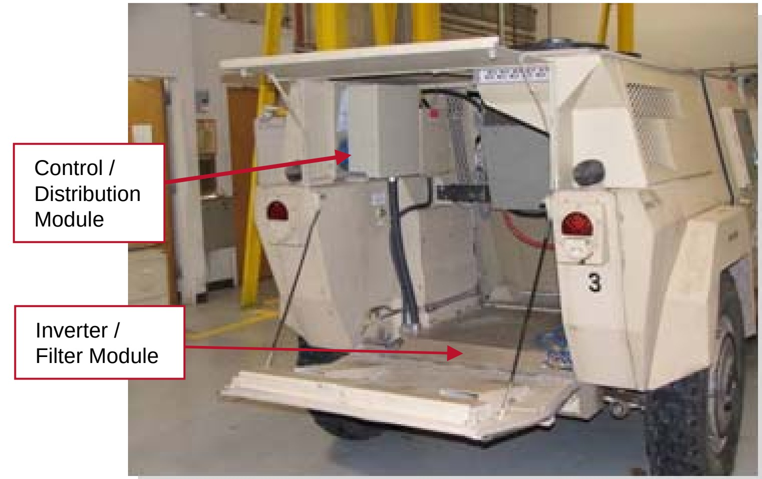
- Developed Under RST-V Program with support of USMC, DARPA, ONR and GDLS
- Provide Power to UOC and Fire Finder Radar
- Goal to Provide Similar Capability to 805 and 813 Gensets
- Exploit Inherent Power Generation Capability of Series Electric Drive


Targeted Applications

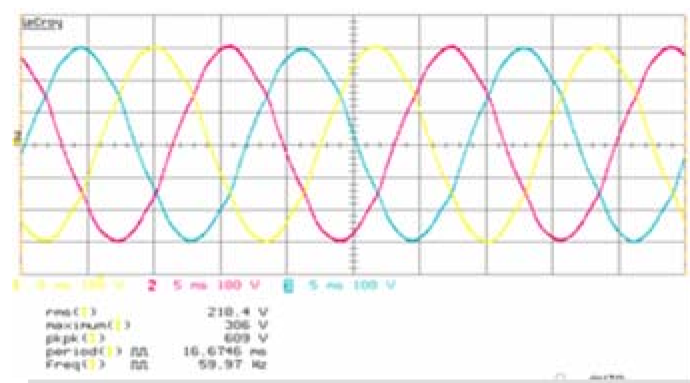
Replaced in Expeditionary Roles

Technical Objectives

- Provide AC Power:
  - 30kW 0.8Pf @ 60 Hz
  - 10kW 0.8Pf @ 400 Hz
  - 208/120VAC 3Φ, 4 wire
  - Mil Std 1332 Class 2A/B
- Synchronize and Load Transfer
- 131°F Operating Temp
- IEC 309, 100 amp connections



Unit Installed on USMC/ONR/DARPA RST-V



Output Voltage Waveform

Approved for Public Release
MCSC 4/20/07

System Description

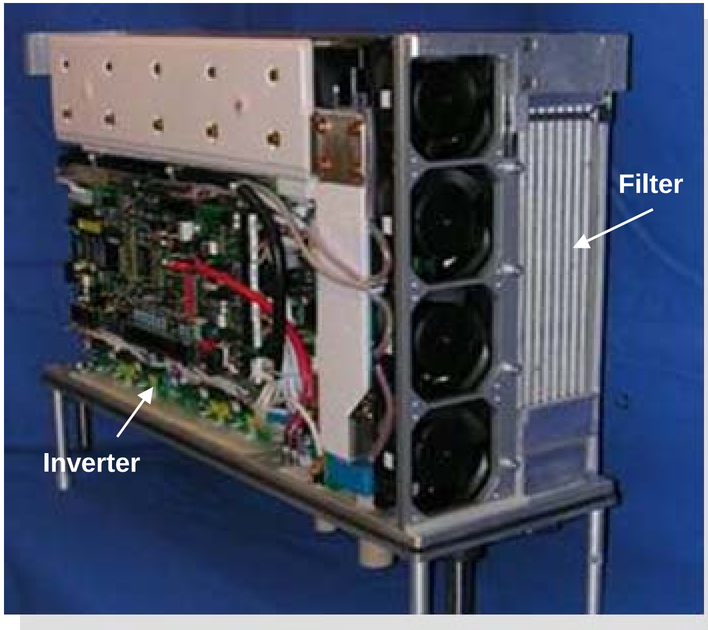
- High Density Solid State DC/AC Inverter System
- Commercial IGBT Based
- PWM Waveform Synthesis
- Three Modules for Adaptable Integration
- Dual Frequency Capability
- Water Cooled Inverter/Filter
- Growth to 50hz and 240/416 VAC output

ACC04 30 kW Inverter / Filter Unit

Interface and Control Panel

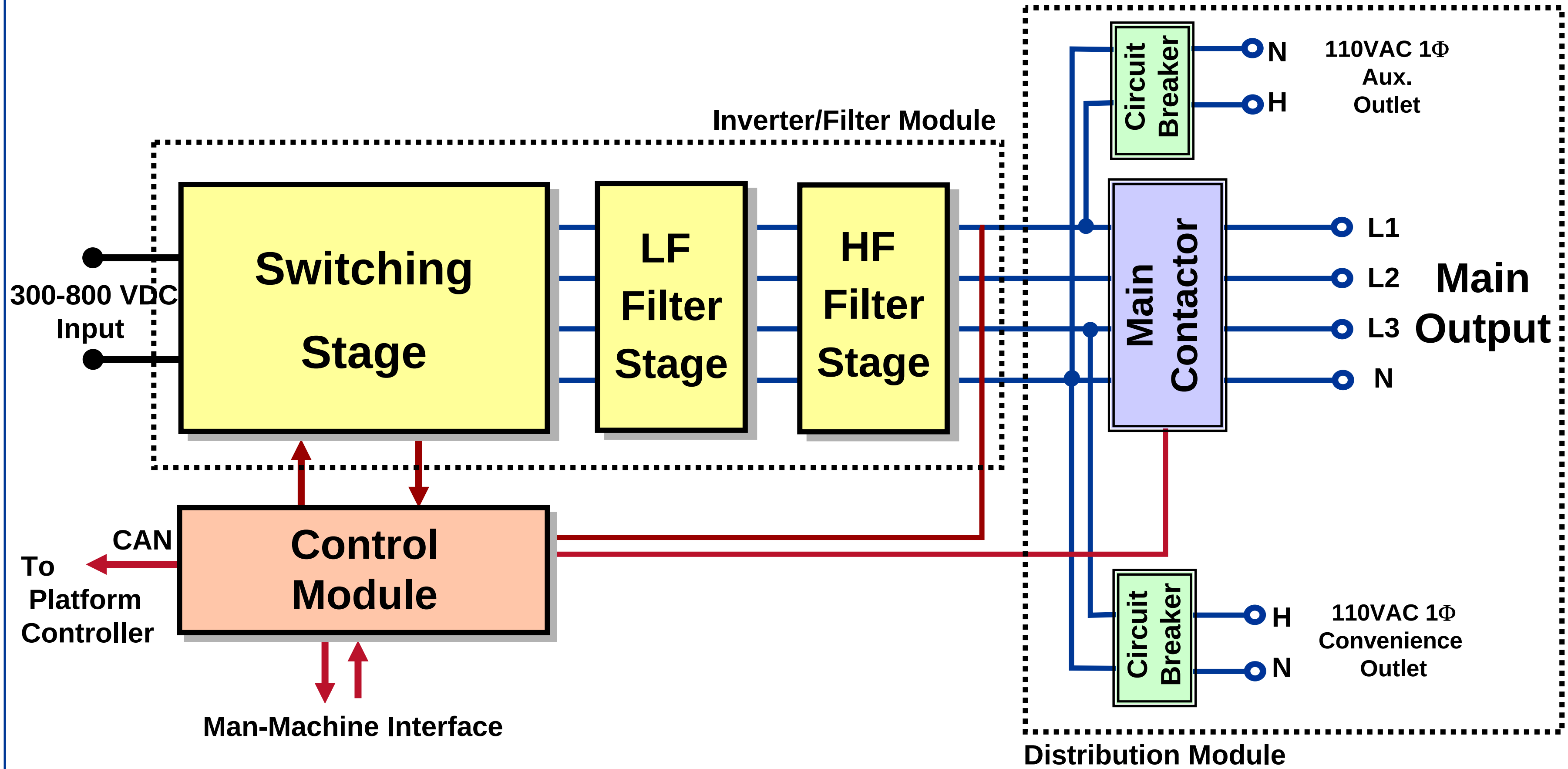
Summary Specifications

- **System Characteristics:**
  - Input Voltage 300-800 VDC
  - Output: 120 / 208 VAC
  - Dual Frequency 60 / 400 Hz
  - WPG Cooled (10 l/min @ 70 °C)
  - Weight 110 kg
  - Volume 85 Liters
  - Voltage Regulation <2%
  - Frequency Regulation <1%

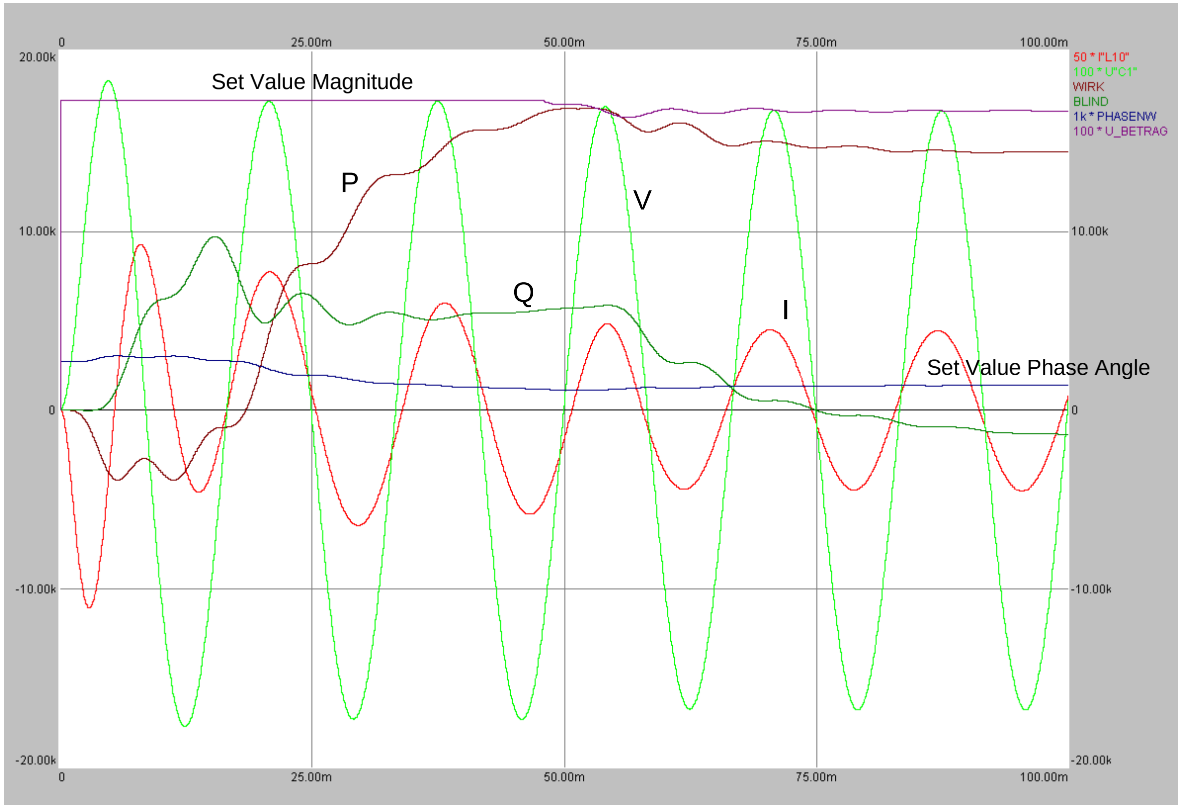


30 kW Inverter/ Filter Module

System Block Diagram



Performance Predictions



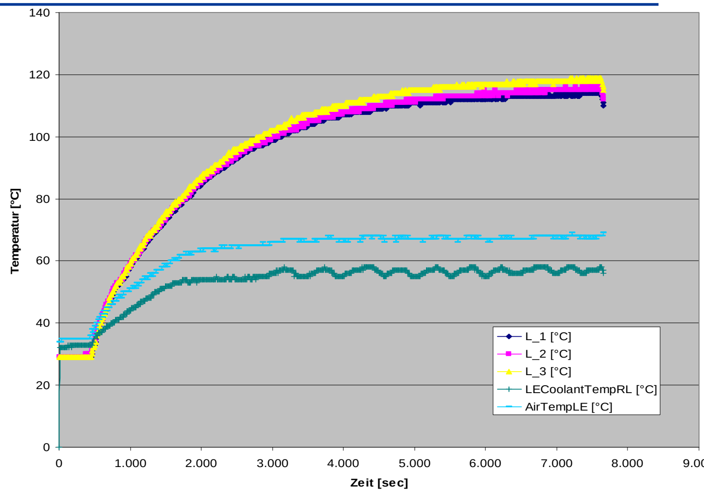
Simulation of Synchronization Process to Grid Stabilization within 75 msec

- **Full Circuit and Control Model Refined and Validated through Lab and Field Testing**

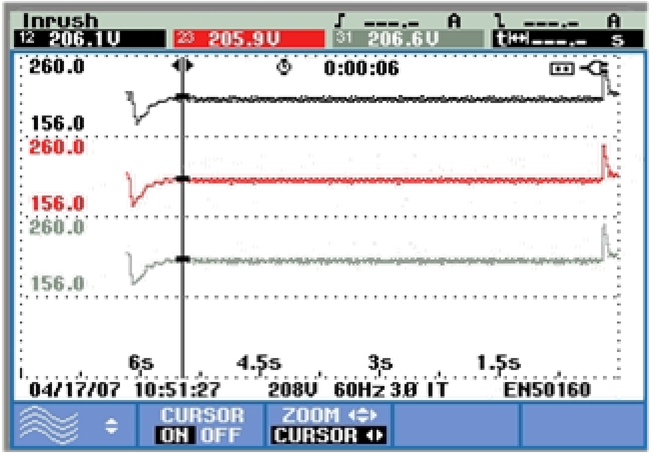
GENERAL DYNAMICS
Land Systems

Performance Testing

- **Full Series Of Development Bench Tests Completed**
- **On Vehicle Lab Testing**
  - ↗ **Inverter / Vehicle Control Tuning**
  - ↗ **Power Quality**
  - ↗ **Load Cycling: Step Apply & Load Dump**
  - ↗ **Inductive Load Start**
  - ↗ **Short Circuit**
  - ↗ **Thermal Limits**



Steady State Thermal Loading



Step Load

GENERAL DYNAMICS
Land Systems

Field & Durability Testing

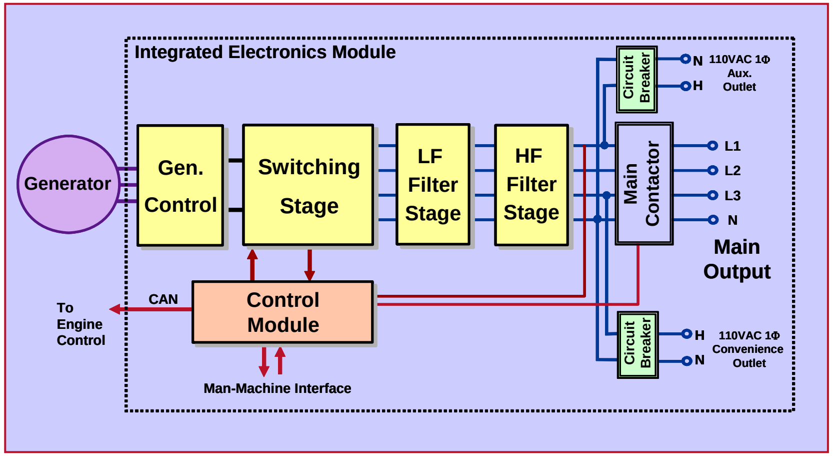
- **Durability Testing**
  - ↗ Mixed Course Durability
  - ↗ 2 hour Export Power Cycles Every 100 Miles
  - ↗ Over 275 hours operation
  - ↗ Reliability Database Established
- **Technical & Durability Testing at APG**
  - ↗ 705 Testing
  - ↗ EMC
  - ↗ Durability Cycles

RST-V with Export Power Units

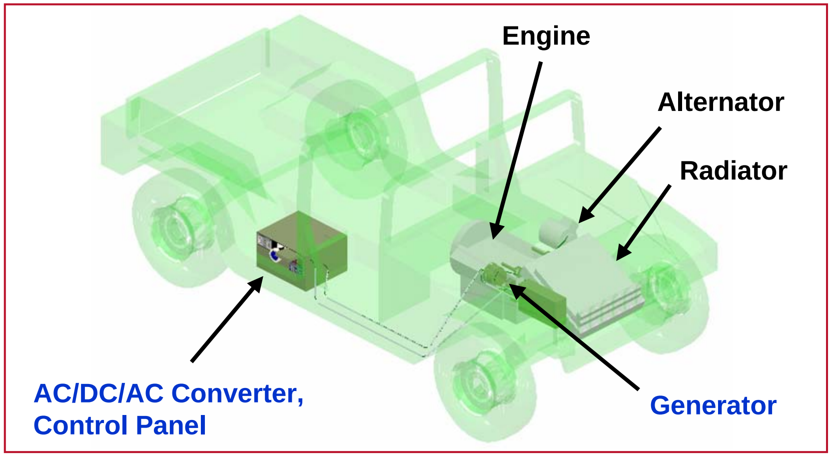
Durability Load Test

Current Developments (Cont.)

- Current System Being Applied to HMMWV
- Core Electronics, Software Repackaged
- High Density PM Generator Added to Provide Power Generation
- Low Impact 20/30 kW Retrofit Kit



Block Diagram



20/30 kW Export Power Concept

Current Developments (Cont.)

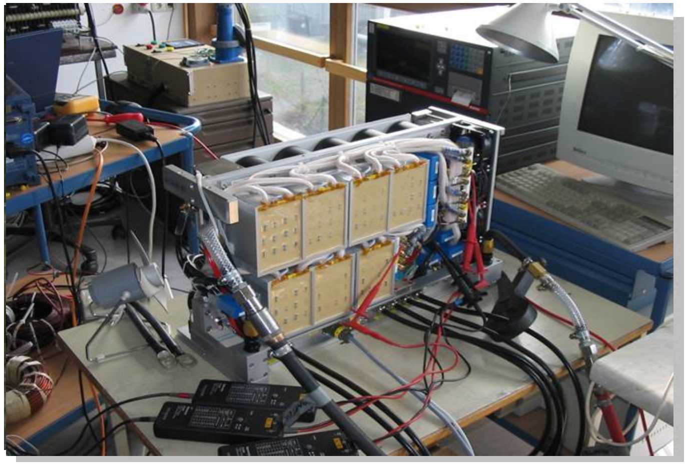
- **Initiating Portability Study to Other Platforms**
- **Initial Focus on Select MRAP Candidates**
- **Scope of Effort:**
  - ↗ **Develop BTA Installation concept for each platform**
  - ↗ **Design Mod Kit including installation hardware**

Portability Study Candidates

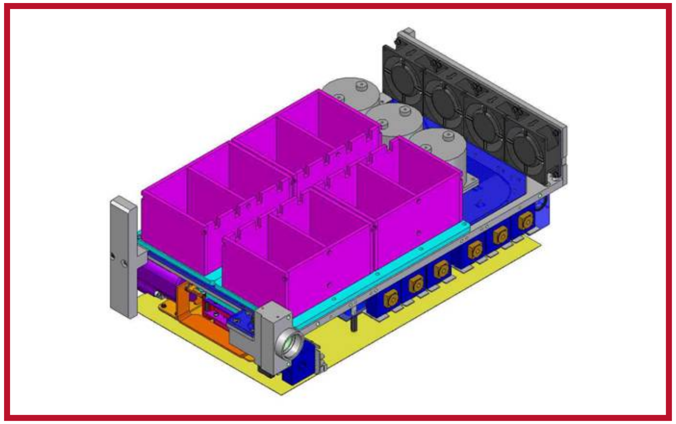
GENERAL DYNAMICS
Land Systems

Summary

- GDLS / Magnet Motor Team Has Demonstrated 30kw Export Power System
- High Density System Reduces Impact to Host Vehicle
- Extending and Refining Design for Portable Application to Wide Range Of Vehicles



Current Generation Remains in Test



Future Electronics Assembly

Hybrid Chemistry Li-ion/VRLA Battery for Silent Watch

Stephen Eaves

Scott Lichte

EnerSys/ModEnergy

Rev. C

The World's Largest Industrial Battery Company

- EnerSys manufactures, markets, and distributes batteries in three markets
  - Reserve Power
  - Motive Power
  - Aerospace & Defense
- Global leader
  - 25% share in the $3.5 billion commercial market
  - Broadest product line in industry
- Leading worldwide presence
  - 21 manufacturing facilities in North America, Europe and Asia
  - 10,000 customers in over 100 countries
- Sales of over $1.3 billion, about 7,550 employees

Modular Energy Devices

Lead-Acid Products

Reserve	Motive	Aerospace and Defense

Reserve

PowerSafe Telecom Products

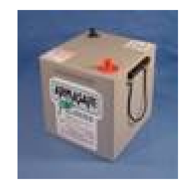
DataSafe UPS Products

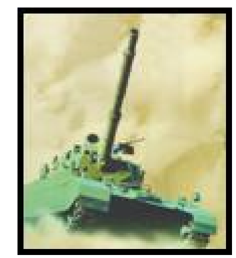
Motive

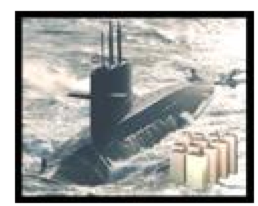
Exide Products

Exide, Hawker and General Products

Aerospace and Defense







Armasafe, Hawker and Varta Products

EnerSys Power/Full Solutions

Modular Energy Devices

The Armasafe Plus (A+) Battery

- 120Ah, 1225 CCA
- Drop-in Operation
- Thin Plate Pure Lead VRLA Technology
- 2X Cold Cranking Amps at -18°C and -40°C vs. 6T
- 10X Cycle Life vs. 6T
- Several years of field use
- Proven in the harshest environments
- Recovery using standard equipment

A+ Silent Watch Test

- 12 A+ Batteries installed in M1A2SEP tank
- 6 in NPS compartment
- 11.3 Hours of Silent Watch at 1350 Watts
- Followed by several starts on only 4 batteries

ModEnergy Lithium-ion Products

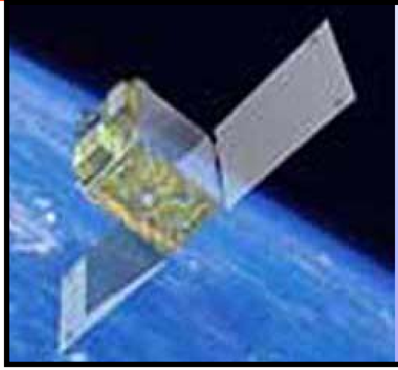
2.5kW for 5 Min. 48V – 19” Rack

67 to 160Ah, 48V, 23” Rack

16 to 220Ah, 14.8V

2.5kW, 5 to 20 Min. 48V

Li-ion Design Team Defense Experience



XSS-11 Satellite
Li-ion Battery Electronics

B2 Bomber
Li-ion Battery Electronics

Navy SEA JET - ¼ Scale Destroyer
720 Hawker 40Ah VRLA Monoblocks

Advanced Seal Delivery System (ASDS)
>1000 cells Li-ion Electronics

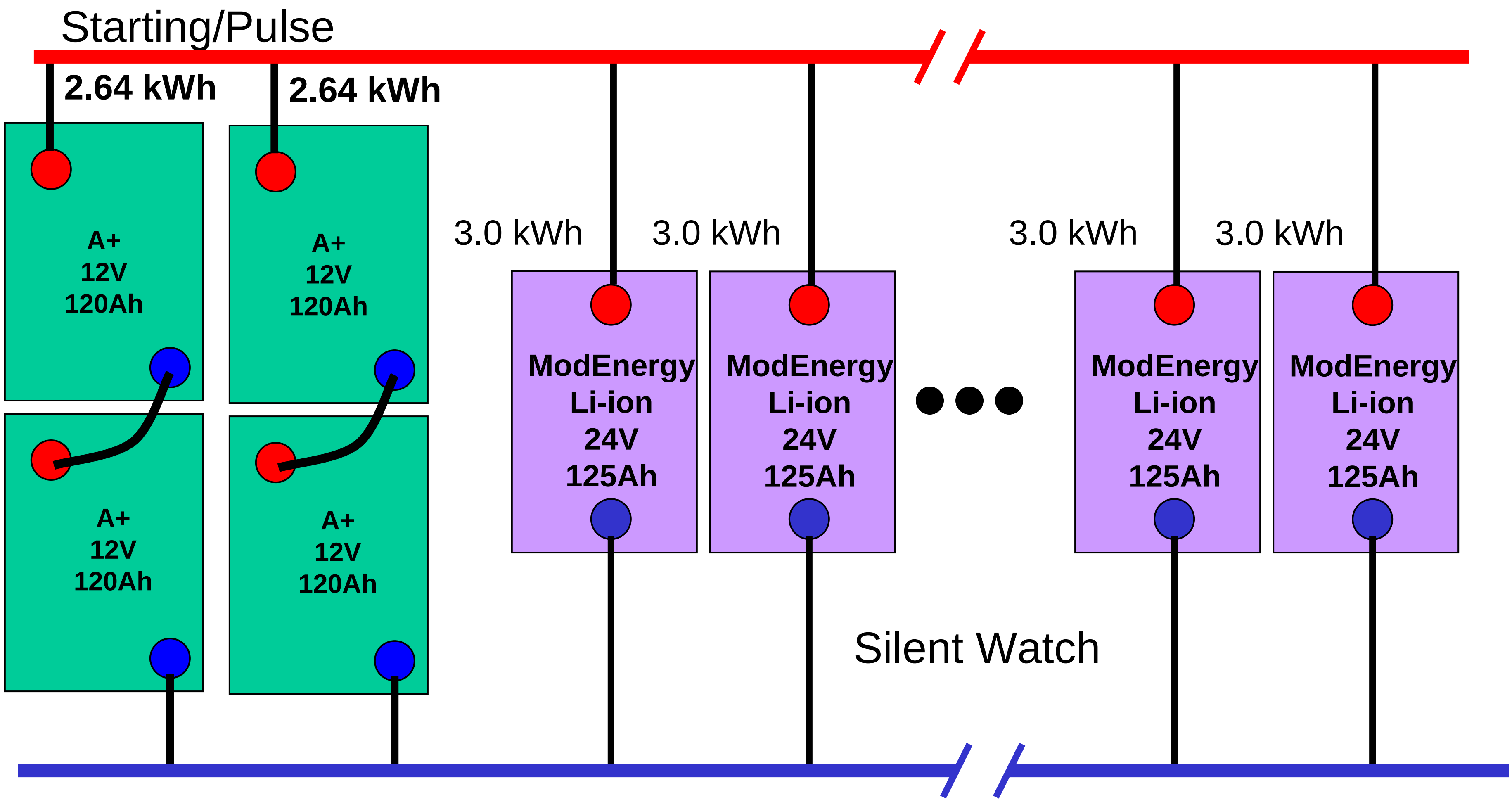
Hybrid Chemistry Design Drivers

- Combine Lithium-ion and ArmaSafe+ Batteries
  - Mitigates technology insertion risk
  - A+ batteries ensure that vehicle will start
  - User may mix A+ and Li-ion as needed
  - Allows safer more compact design by off loading pulse power to A+
- Li-ion must closely match envelope of A+ battery
- Seamless operation on 28V Bus
- Bus Conforms to MIL-STD-1275D
- Derive guidance where applicable from MIL-PRF-32143

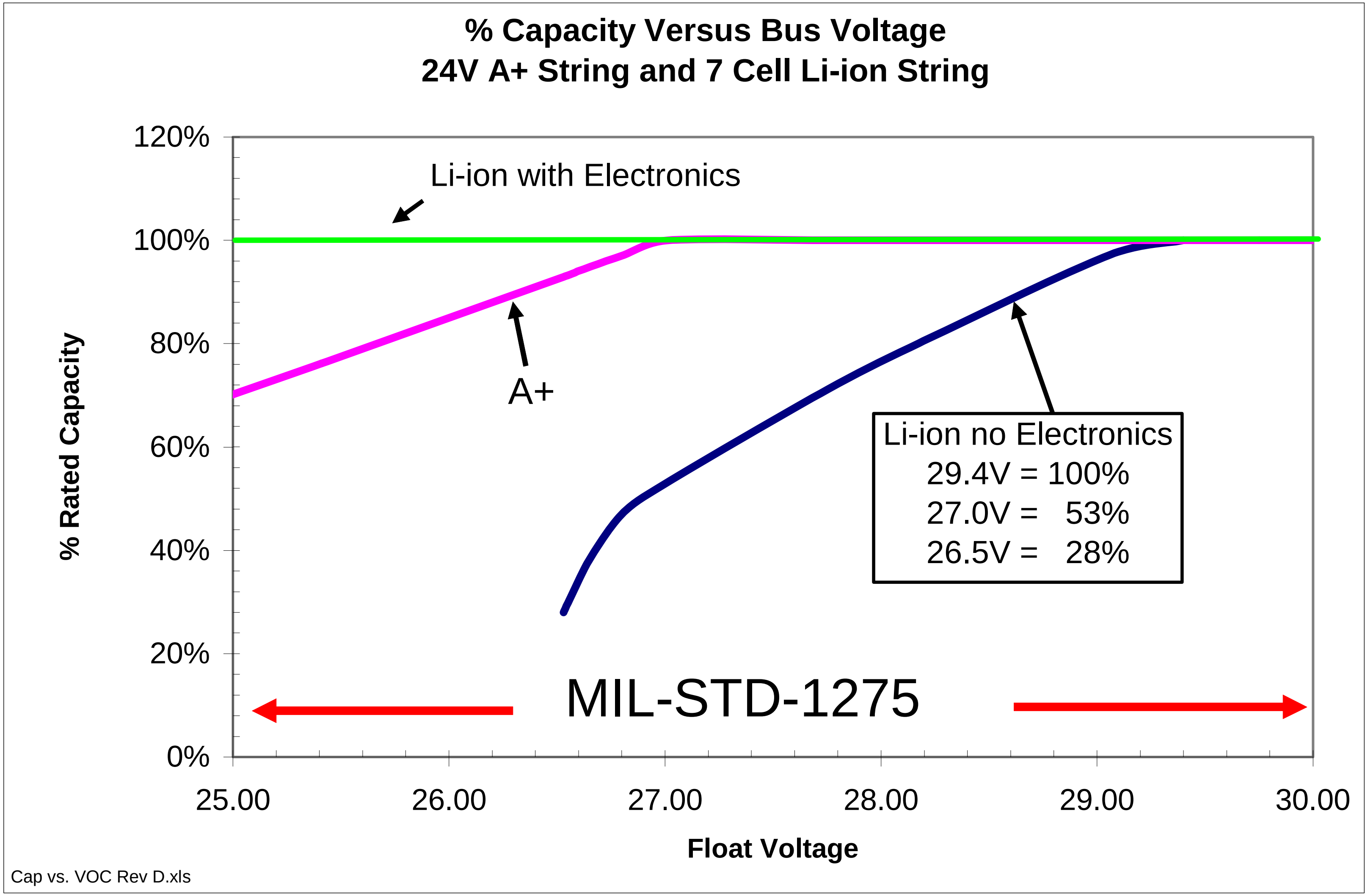
Hybrid Chemistry Design Drivers

- Utilize ModEnergy Redundant Array Architecture
  - Very high reliability numbers
  - Cell failure is isolated and does not disable battery
  - Uses mass produced, UL1642 approved cells
- Base design on COTS Li-ion modules
  - UL, UN Approvals
  - Cost and availability advantages
  - High level of quality from established production

28V Bus Architecture



Charging Under MIL-STD-1275



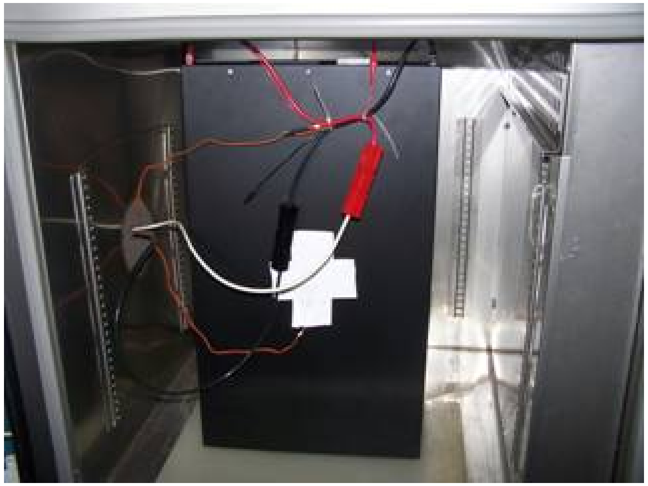
Li-ion Building Block

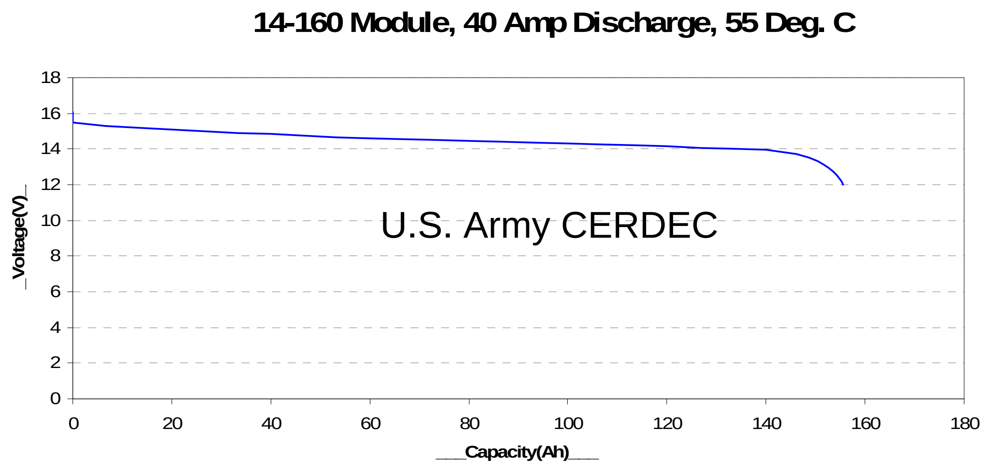
Capacity Option Code -C__	Rated Capacity (Ah)	D Case Depth (In)	D Case Depth (mm)	Module Weight (Lbs)	Module Weight (kg)
28	28	4.075	103.5	6.66	3.03
38	38	4.875	123.8	8.25	3.75
47	47	5.675	144.1	9.84	4.47
56	56	6.475	164.5	11.44	5.20
66	66	7.275	184.8	13.03	5.92
75	75	8.075	205.1	14.62	6.65
85	85	8.875	225.4	16.22	7.37
94	94	9.675	245.7	17.81	8.10
103	103	10.475	266.1	19.41	8.82
113	113	11.275	286.4	21.00	9.55
122	122	12.075	306.7	22.59	10.27
132	132	12.875	327.0	24.19	10.99
141	141	13.675	347.3	25.78	11.72
150	150	14.475	367.7	27.37	12.44
160	160	15.275	388.0	28.97	13.17
169	169	16.075	408.3	30.56	13.89
179	179	16.875	428.6	32.15	14.62
188	188	17.675	448.9	33.75	15.34
197	197	18.475	469.3	35.34	16.06
207	207	19.275	489.6	36.94	16.79
216	216	20.075	509.9	38.53	17.51
226	226	20.875	530.2	40.12	18.24
235	235	21.675	550.5	41.72	18.96
244	244	22.475	570.9	43.31	19.69
254	254	23.275	591.2	44.90	20.41
263	263	24.075	611.5	46.50	21.14

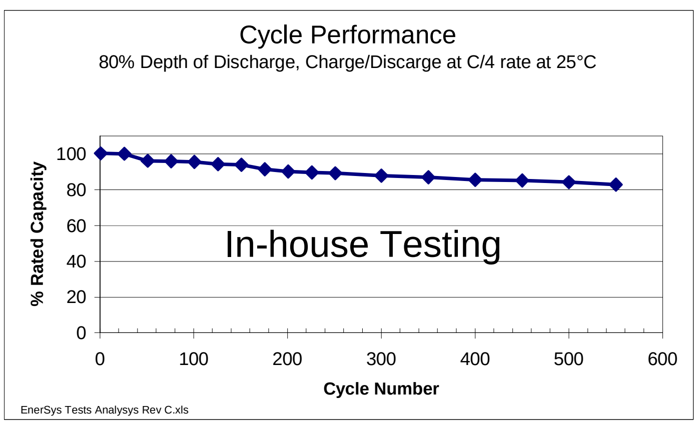
11.1V, 103Ah, 8.8Kg

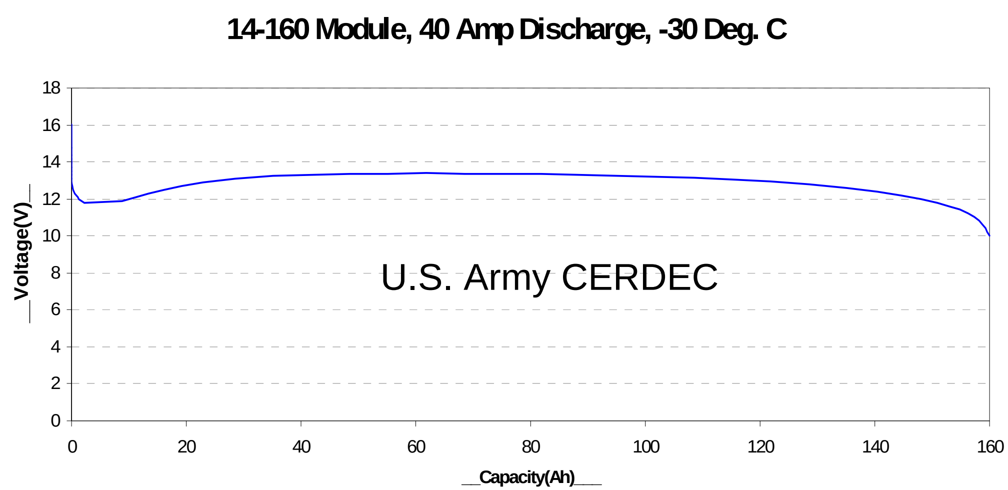
Design uses 3 modules with DC-DC converter. Equivalent to 125Ah at 24V considering 86% efficiency

Li-ion Performance Testing







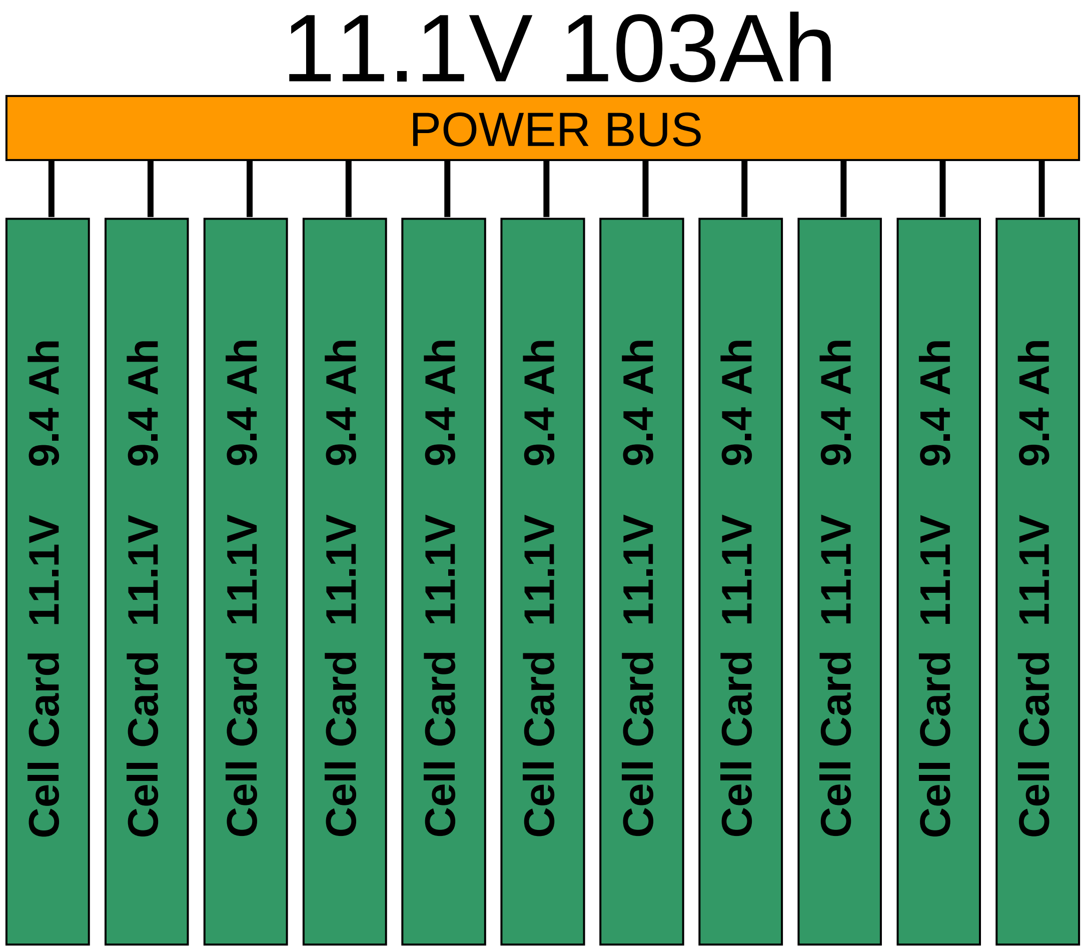


EnerSys Power/Full Solutions

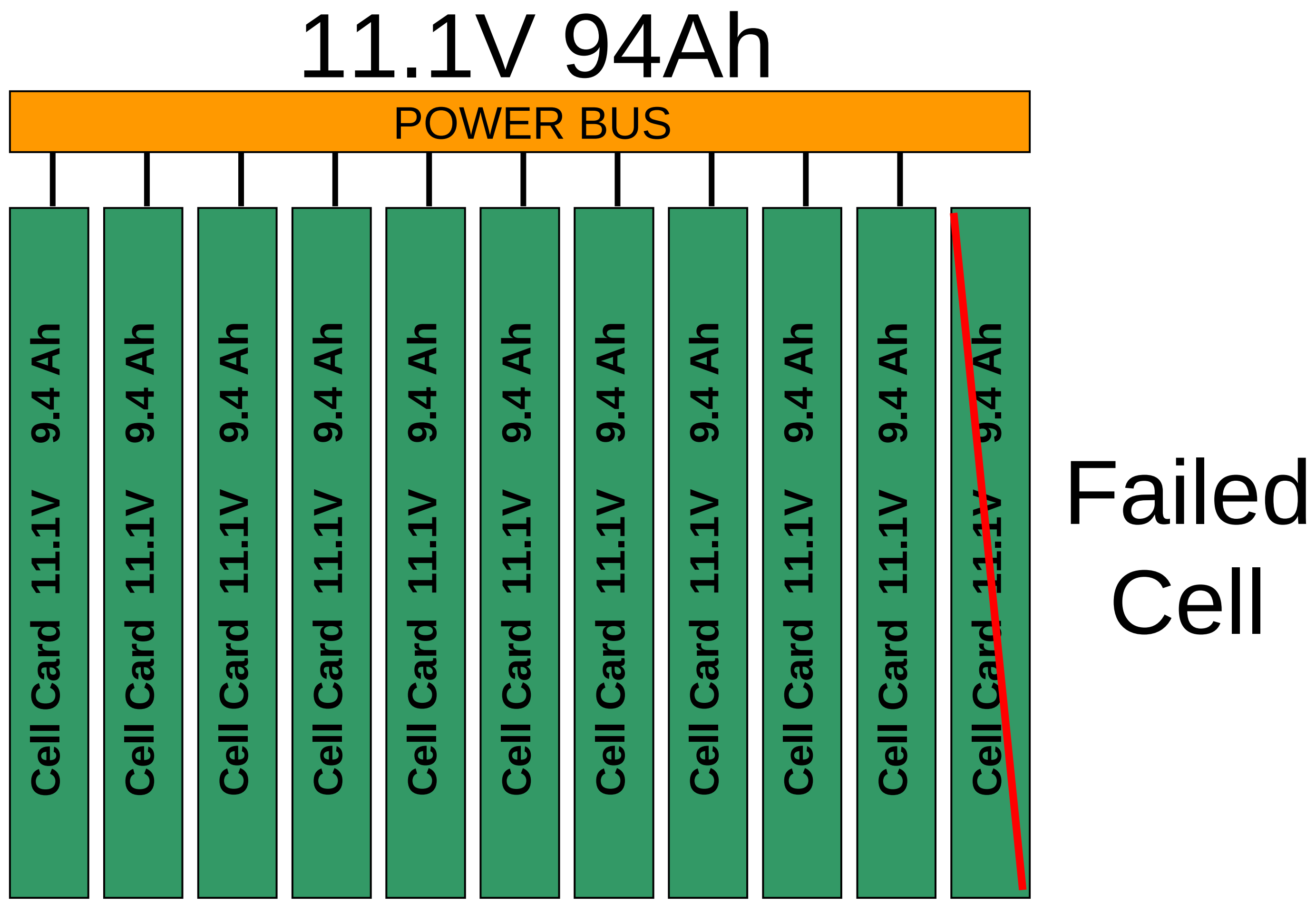
Modular Energy Devices

www.ModEnergy.com

Redundant Cell Array Technology (RedCAT^{tm})



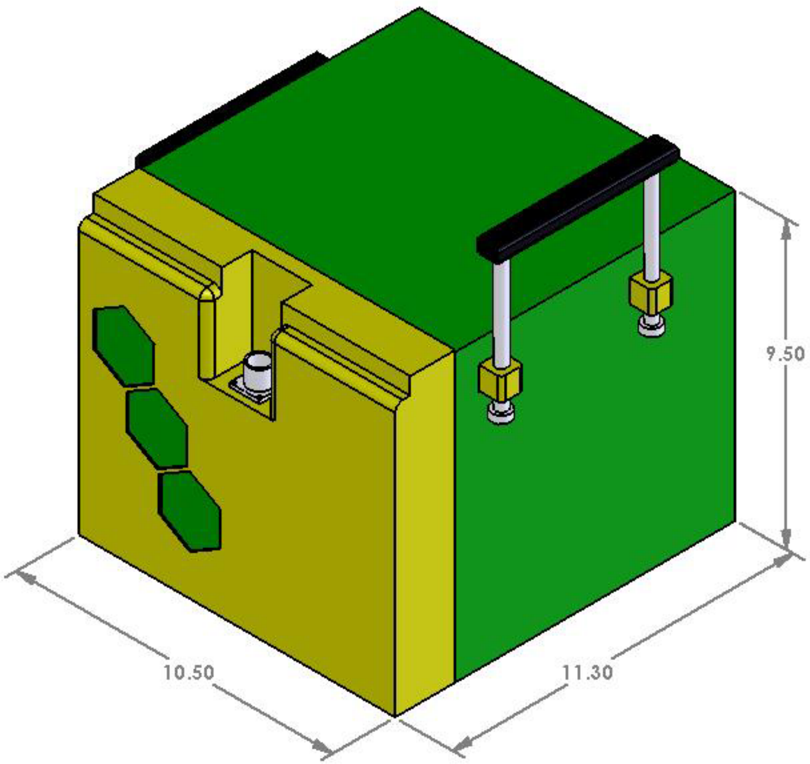
Redundant Cell Array Technology (RedCAT™)



A+ and Li-ion Module Specifications

Characteristic	Li-ion	A+
Acceptable Charge Voltage	18 - 36	13.5 to 15
Discharge Volt Range	27	13.2 to 10
Charge time to 90%, @ -40°C (Hours)	7.6	3 to 5
Cranking Current, 30 Sec @ -40°C	20	>400
Energy 25 Deg. C, 4 Hour Rate (kWh)	3	1.32
Energy -40 Deg. C, 4 Hour Rate (kWh)	2.25	0.53
Op. Temp. Range (°C)	-40 to 65	-40 to 80
Cycle Life, 80% DoD	500	320
Weight (kg)	33	39
Width (mm)	267	267
Height (mm)	241	231
Depth (mm)	287	287

Conceptual Module Design



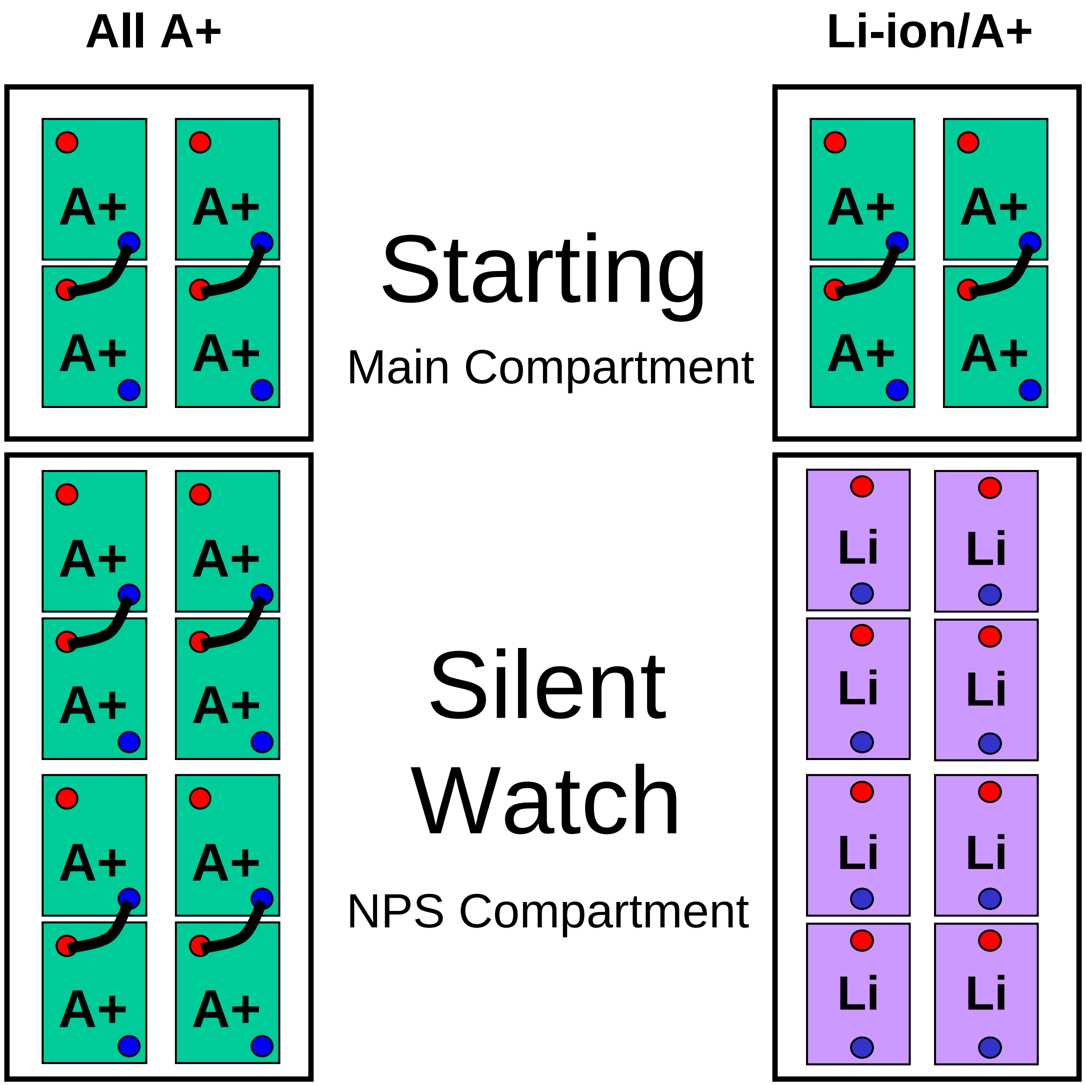
Li-ion

A+

Vehicle Architecture

- A+ and Li-ion batteries work in parallel on the 28V bus
- Li-ion power electronics accommodate MIL-STD-1275
- A+ batteries provide starting and pulse currents
- Li-ion provides extended Silent Watch capabilities

A+ and Li-ion/A+ Configuration M1A2SEP Vehicle



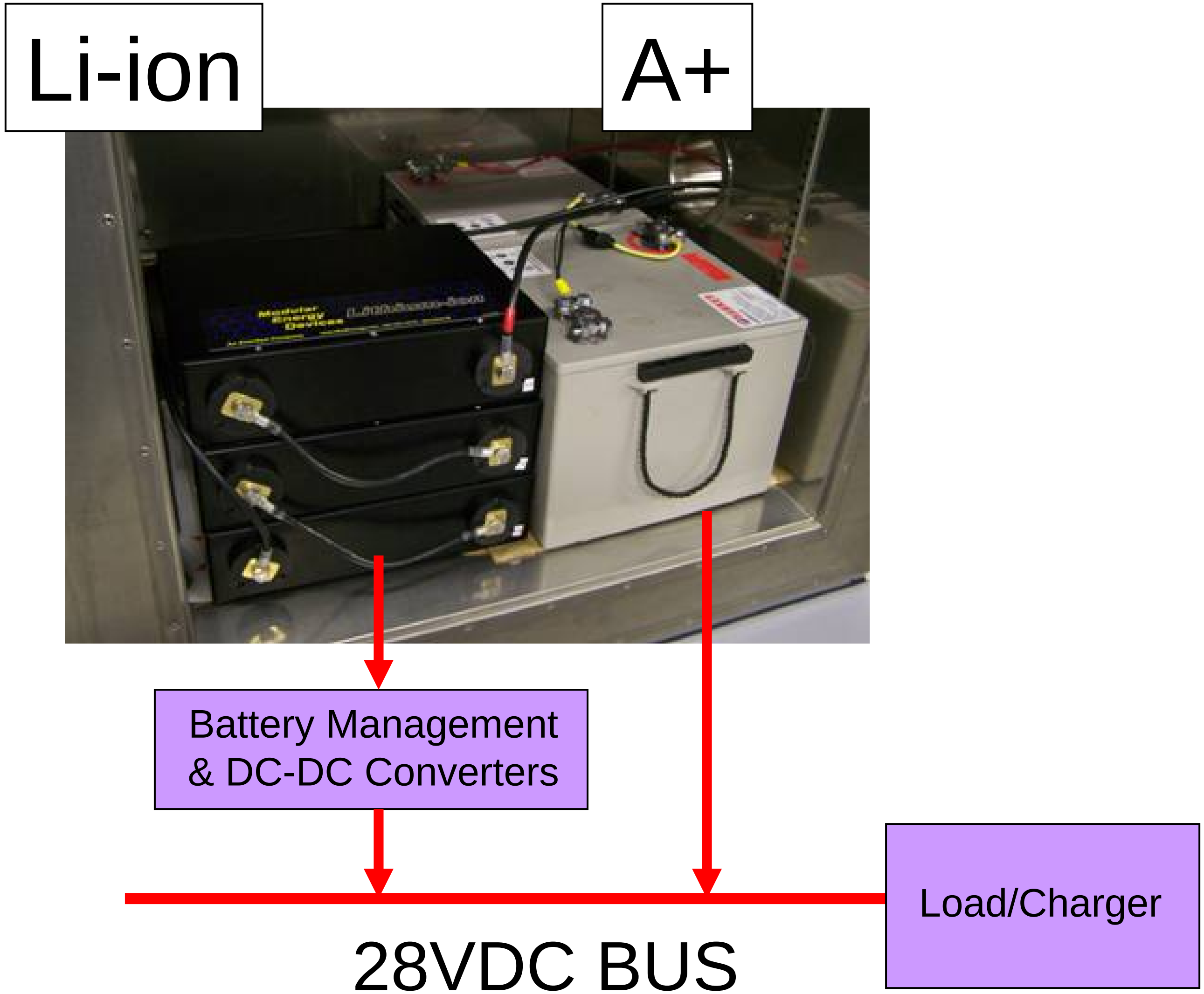
M1A2SEP Vehicle Design Specifications

Characteristic	Li-ion/A+	A+
Modules	12	12
Cranking Current @ -40°C	>960	>2400
Energy 25°C, 4 Hour Rate (kWh)	29.3	15.8
Energy -40°C, 4 Hour Rate (kWh)	20.12	6.36
Run Time @ 1.5kW 25°C (Hrs)	19.5	10.6
Run Time @ 1.5kW -40°C (Hrs)	13.4	4.2
Volume (l)	218.5	212.4
Weight (kg)	420	468
Energy Density Wh/l @ 25°C	134.0	74.6
Specific Energy Wh/kg @ 25°C	69.7	33.8

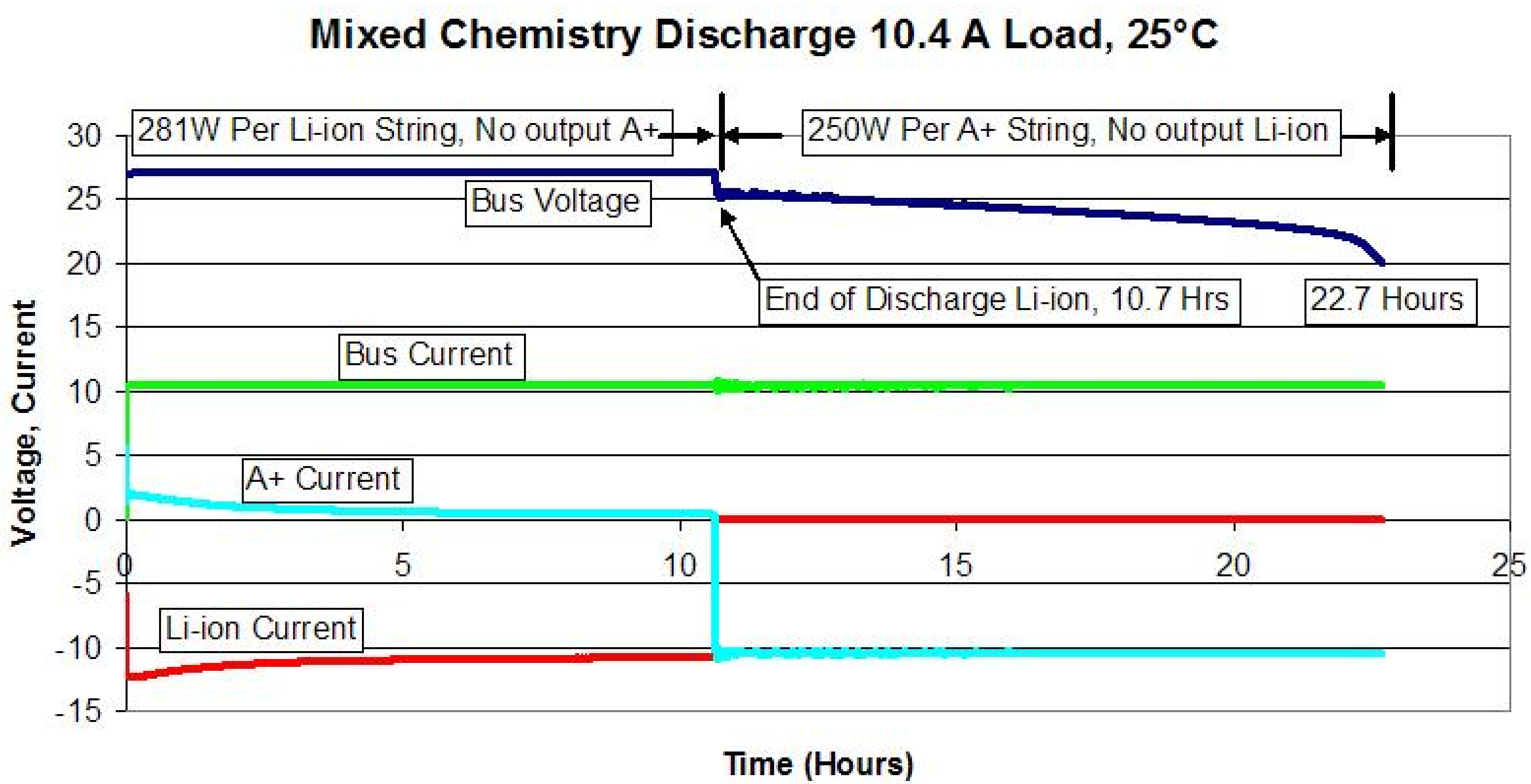
Testing

- Single string of A+ in parallel with single Li-ion String
- 25°C and -40°C
- 10.4 A Load
- 280W/String from Li-ion
- 250W/String from A+
- Scales to 2246W on M1A2SEP concept Li-ion Only
  - (8 strings x 280W = 2264W)
- Scales to 500W when down to A+ only operation
  - (2 strings x 250W = 500W)

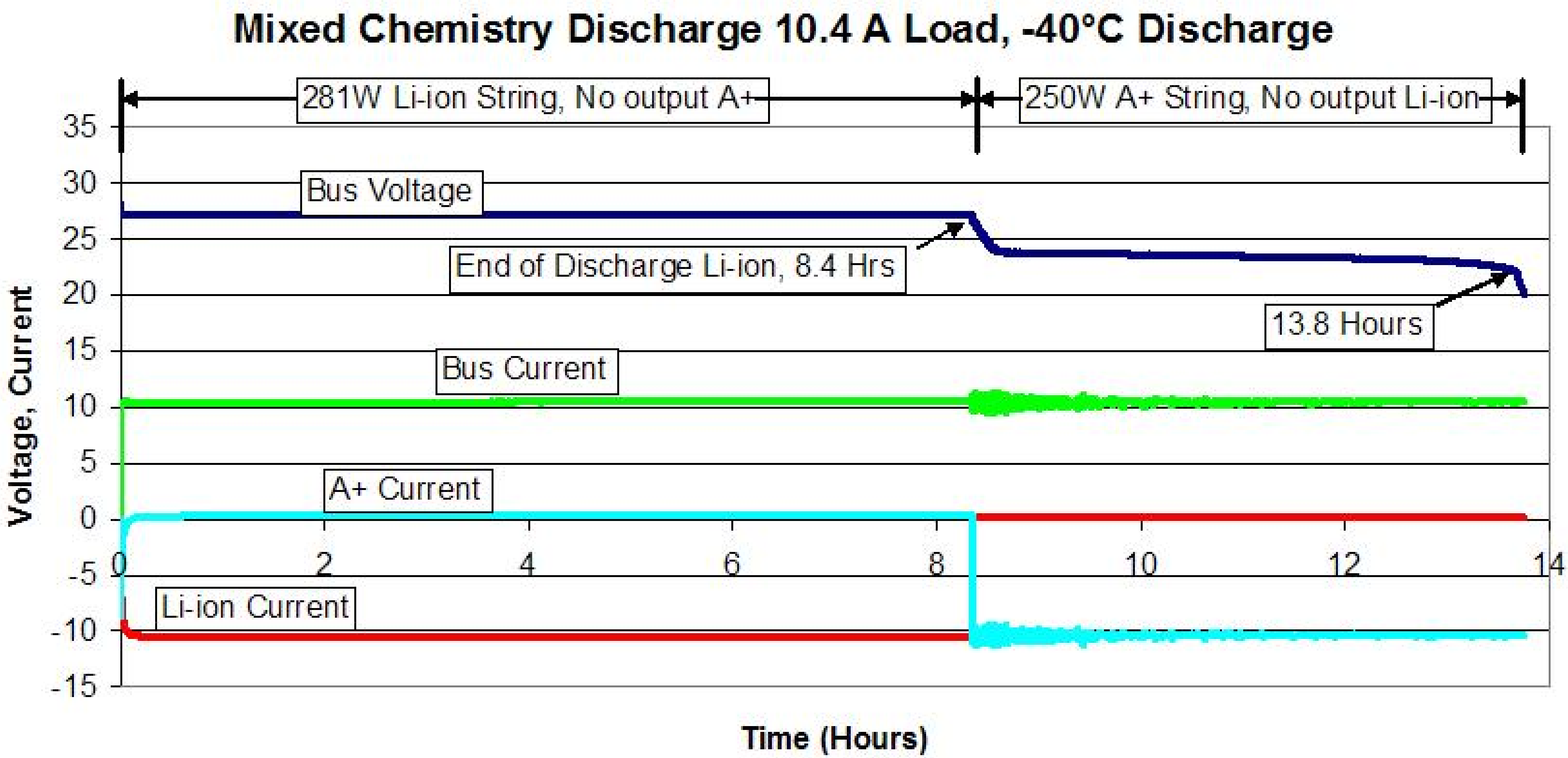
Test Configuration



25° Discharge Mixed Chemistry



-40° Discharge Mixed Chemistry



Test Summary, Mixed Chemistry

Parameter	25°C	-40°C
Bus Current	10.4	10.4
Li-ion Run Time	10.7 hrs	8.4 hrs
A+ Run Time	12 hrs	5.4 hrs
Total Run Time	22.7 hrs	13.8 hrs
Total Energy	6 kWh	3.7 kWh

Conclusions

- Li-ion can operate in parallel with Armasafe Plus (A+) batteries
- Li-ion power electronics meet MIL-STD-1275 bus voltage requirements
- The system can be configured to use Li-ion first and leave A+ on reserve for starting and reserve energy if necessary
- The user can mix A+ and Li-ion as needed
- 2X runtime vs. A+ alone at 25°C
- 3X runtime vs. A+ alone at -40°C

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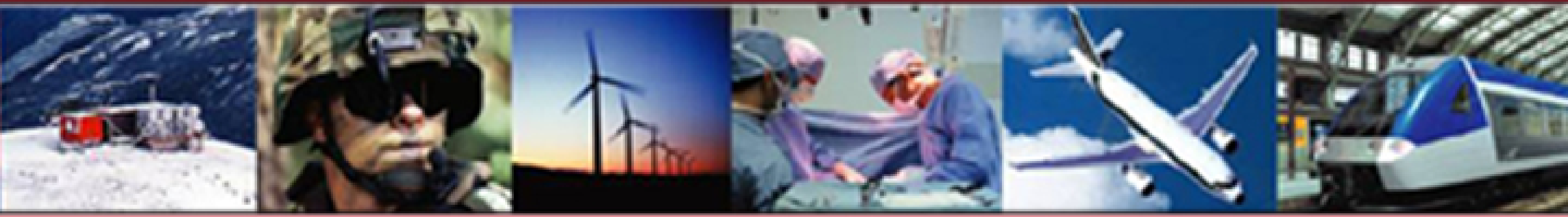
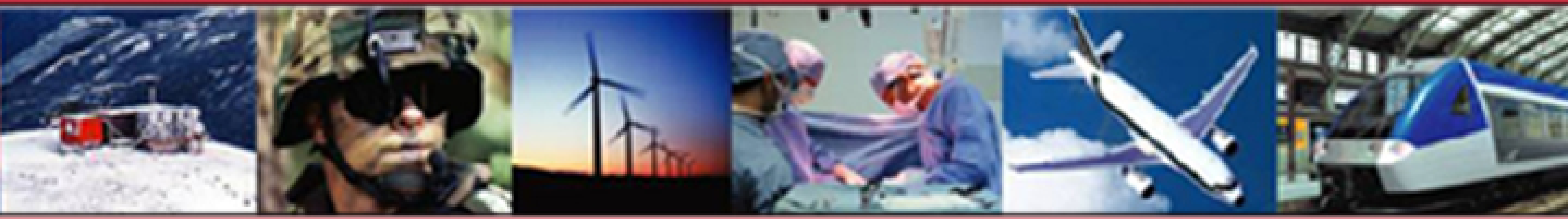
2007 Joint Services Power Expo & Conference

Leadership in Battery Technology



Recent Advances in Saft Li-ion

Bridget Deveney



Broad Product Range

Military Applications

DOD's Main Provider of Primary Lithium Batteries

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- **World's leading supplier of primary Lithium batteries the U.S. military**
- **Offer complete range of technologies: Li-SO_2, Li-$SOCl_2$, Li-MnO_2**
- **Supporting our troops in Iraq - producing over 120,000 BA-5590s per month - during 24-7 operations for >2 years non-stop**
- **Delivered >90% of OIF and OEF Primary Batteries**

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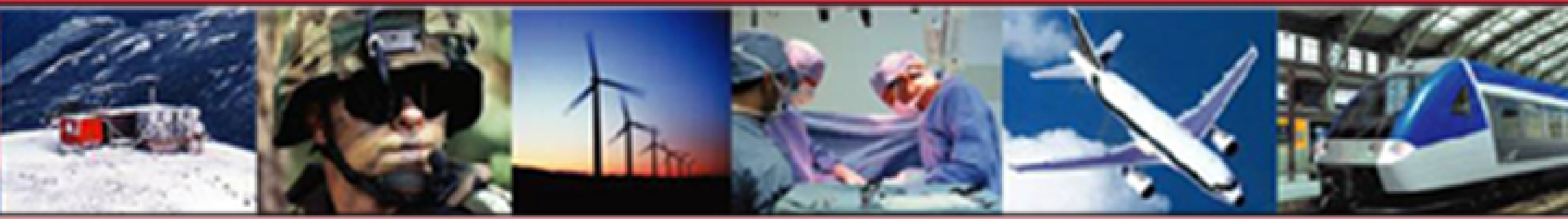
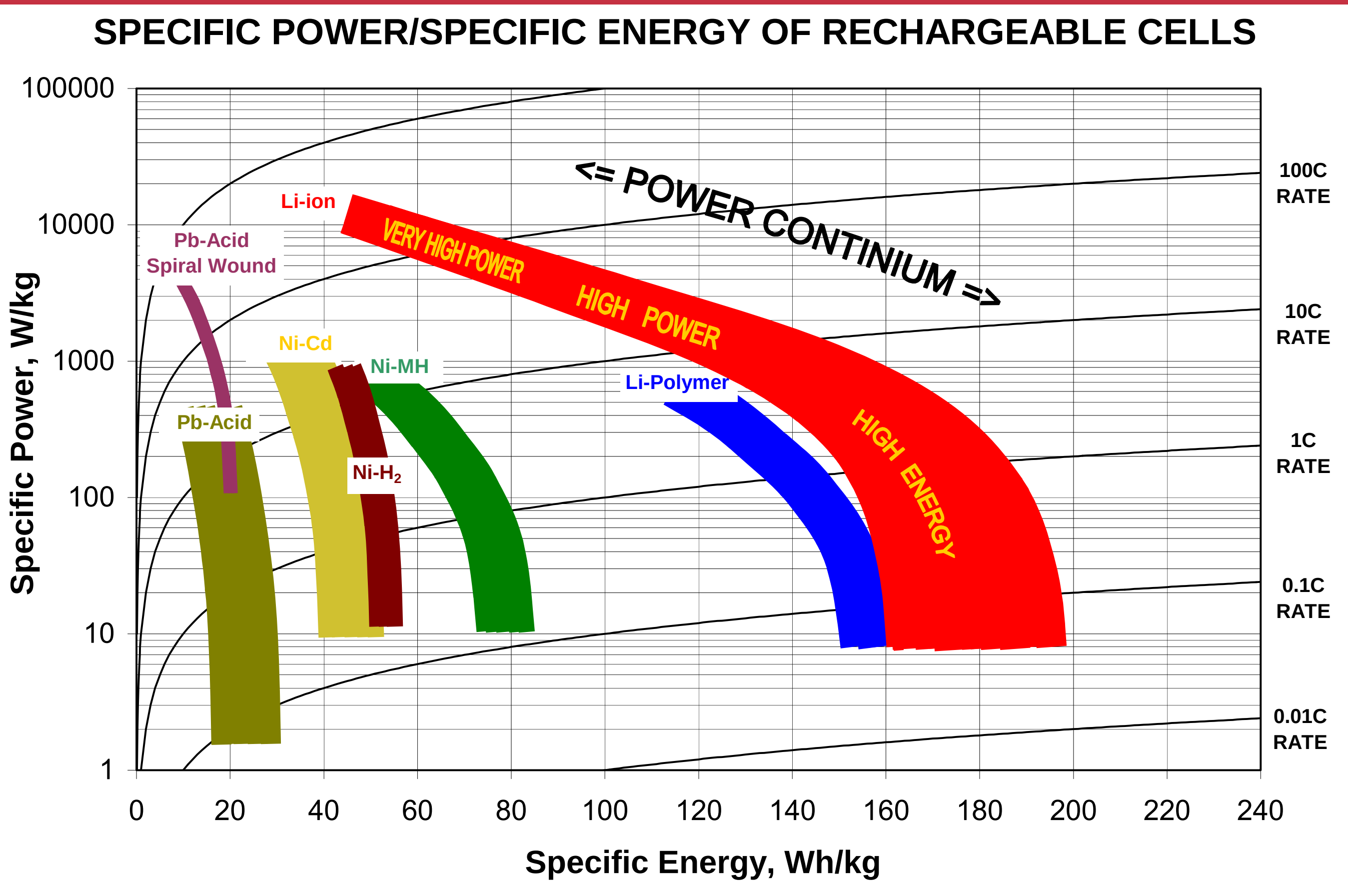
High Power Lithium Ion

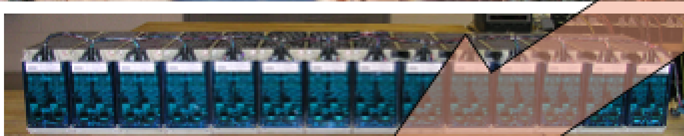


Advanced Li-ion Technology

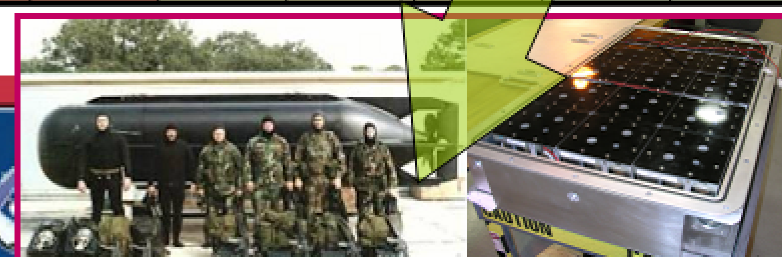


Space & Defense Division Cockeysville, MD

Dedicated to manufacturing advanced Li-ion cells and batteries for Space and Defense application

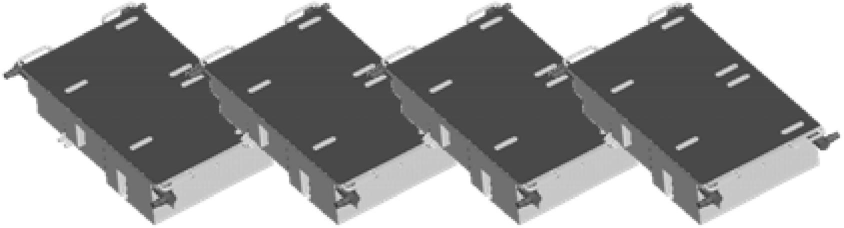


Type of Cell	VL4V Very High Power	VL8V Very High Power	VL8P High Power	VL16P High Power	VL30P High Power	VL44E High Energy	VL50E High Energy
Dimension							
Diameter (mm)	34	41	47	47	54	54	54
Case Length (mm)	156	156	104	178	208	220	208
Mass (kg)	0.33	0.47	0.38	0.67	1.05	1.12	1.05
Capacity (AH)	5.5	8.6	8	16	31	44	51
Specific Energy (Wh/kg)	60	65	75	85	106	140	175
Energy Density (Wh/L)	138	155	158	187	234	300	390
Power (W/kg)							
→ 18 sec. Pulse (at 50% SOC)	3600	4000	1420	1430	1190	NA	NA
→ Continuous	2100 (60C)	2500 (60C)	850 (15C)	950 (15C)	800 (10C)	278 (2.6C)	60 (C/2)



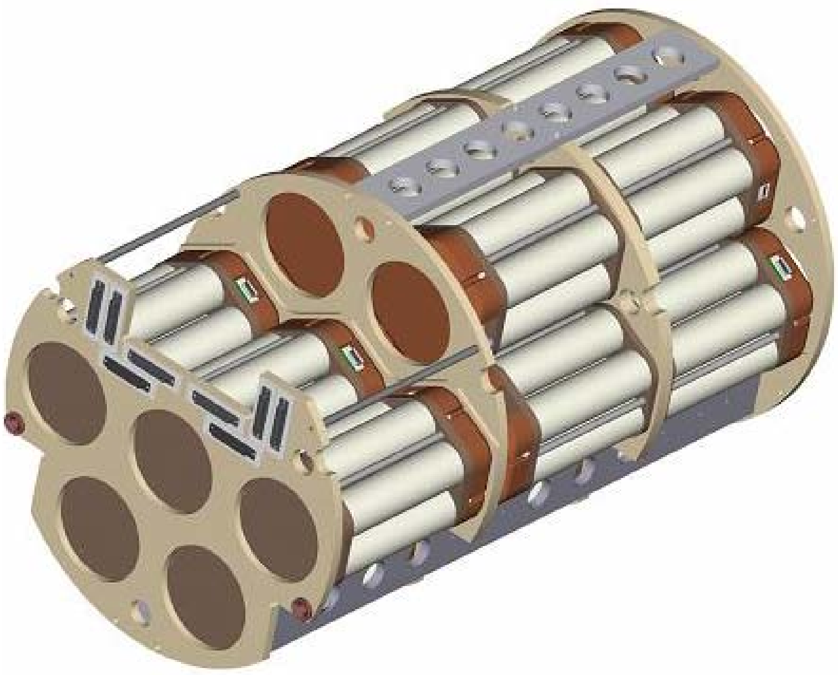

Defense Applications

SEAL Delivery Vehicle



- Lithium Ion Battery with 50% Energy Improvement
- Dual Redundancy for Improved Safety and Survivability
- Major Life Cycle Cost Savings

AUV Power



- **21” High Energy System**
- **Modular Approach with Standard Cell and CANProbe Board**

ITAS Improved Target Acquisition System

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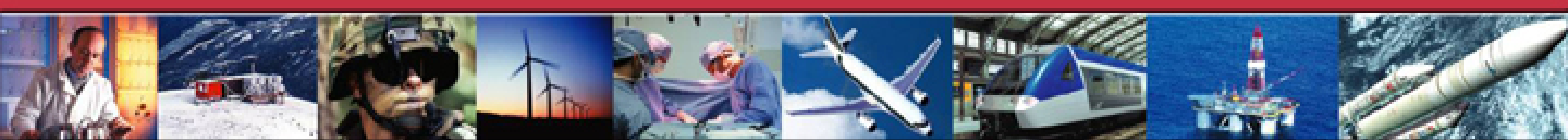
Raytheon

Li Ion Battery



JSF 270 V Battery

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- **First producible 270V Aviation Battery**
- **85 lbs, 1kWh over full temperature range**
- **Pursuing full qualification**

High Power Experience

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- SAFT has been working on high power Li-ion since 1995.
- The Very High Power technology is a natural evolution for SAFT's Li-ion expertise.
- SAFT is already participating in the development phase of DE Applications
  - **A Solid State Heat Capacity Laser (SSHCL) program is under way in Laurence Livermore National Laboratory**
- SAFT is gearing up to manufacture VHP products. A good example is the Joint Strike Fighter Aircraft program where a 270V Emergency Battery using VL4V cells is under development and qualification

48 Volt High Power Module

- Discharge Current: 250 A typical
- Peak Power: 8 kW / kg (continuous discharge)
- Pulse Power: 12 kW / kg (2 sec duration)
- Charge Current: 100 A max
- Battery Capacity: 8 Ahrs
- Stored Energy: > 345 Whrs

- Module Weight 7.6 kg (16.8 lbs)
- Module Voltage Max: 49.2 V (charged)

  Avg: 43.2 V

  Min: 36.0 V


Cutting Edge
Development

$LiFePO_4$ Development

- **What is Iron Phosphate and why are people talking about it?**
  - UT & Phostech
  - Technology benefits and cost

LiFePO$_4$ Development

- **SAFT initiated work on LiFePO$_4$ under a developmental program with Army Research Laboratory**
  - SAFT contributed with high power electrode and cell design expertise
  - The scientists at ARL developed advanced electrolytes targeting life and improvement

- **SAFT is continuing the LiFePO$_4$ work under US Army MANTECH effort. Very High Power cells with the LiFePO$_4$ cathode have been produced using standard hardware. These cells are undergoing testing.**

- **In all this work SAFT is using material from the only licensed by UT supplier of LiFePO$_4$ – Phostech/Sud-Chemie.**

LiFePO4 Development

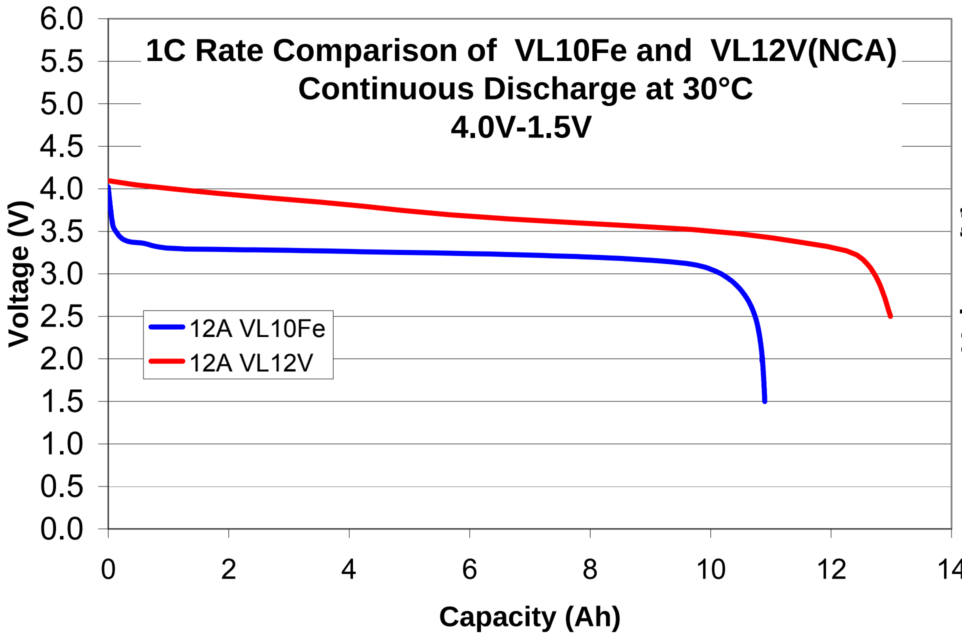
saft

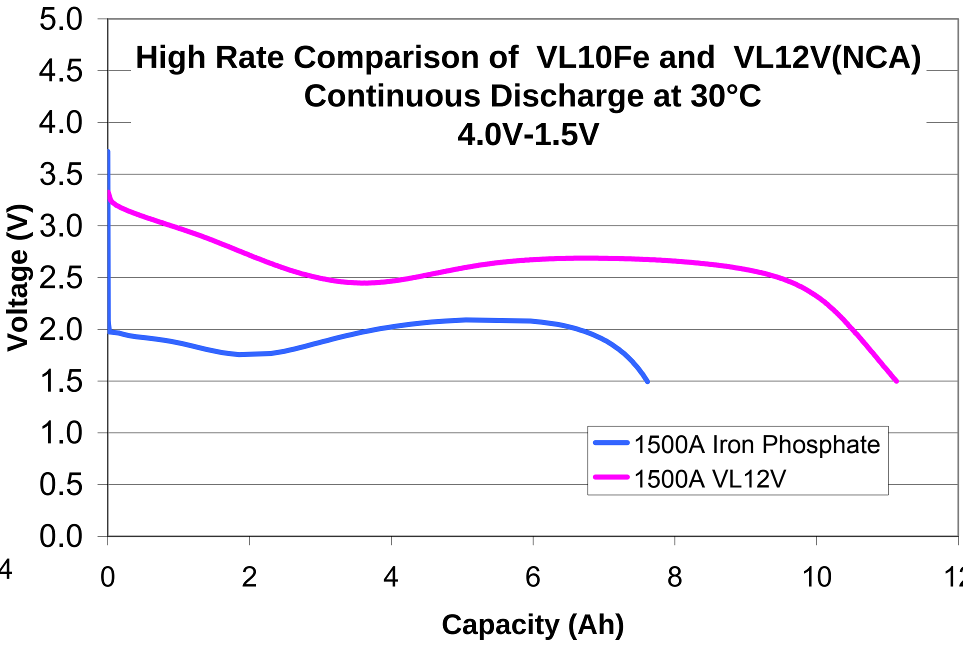
Cell	VL10Fe	VL12V
Cathode	$LiFePO_4$	NCA
Nominal Voltage (V)	3.3	3.6
Nominal Capacity at C rate (Ah)	10	12
V = f(SOC) at 50% DoD at C rate (mV/SOC%)	0.13	0.66
Maximum Discharge Current at 25°C (A)		
Continuous	1500	1500
2s Pulse	1700	2200
200ms pulse	2200	3200
Specific Energy (W/L)	54	74
Energy Density (Wh/L)	128	175
Specific Power at 25°C 100% SOC (W/kg)		
Continuous	4375	4600
2s Pulse	5000	6800
200ms Pulse	6400	10,000

LiFePO$_4$ Development

- **Performance parameters Important for use in military application**
  - Availability of very high power
  - Operation at wide temperature range from -40^{o}C to 72^{o}C
  - Retention of low temperature power after exposure to high temperature

LiFePO$_4$ Development

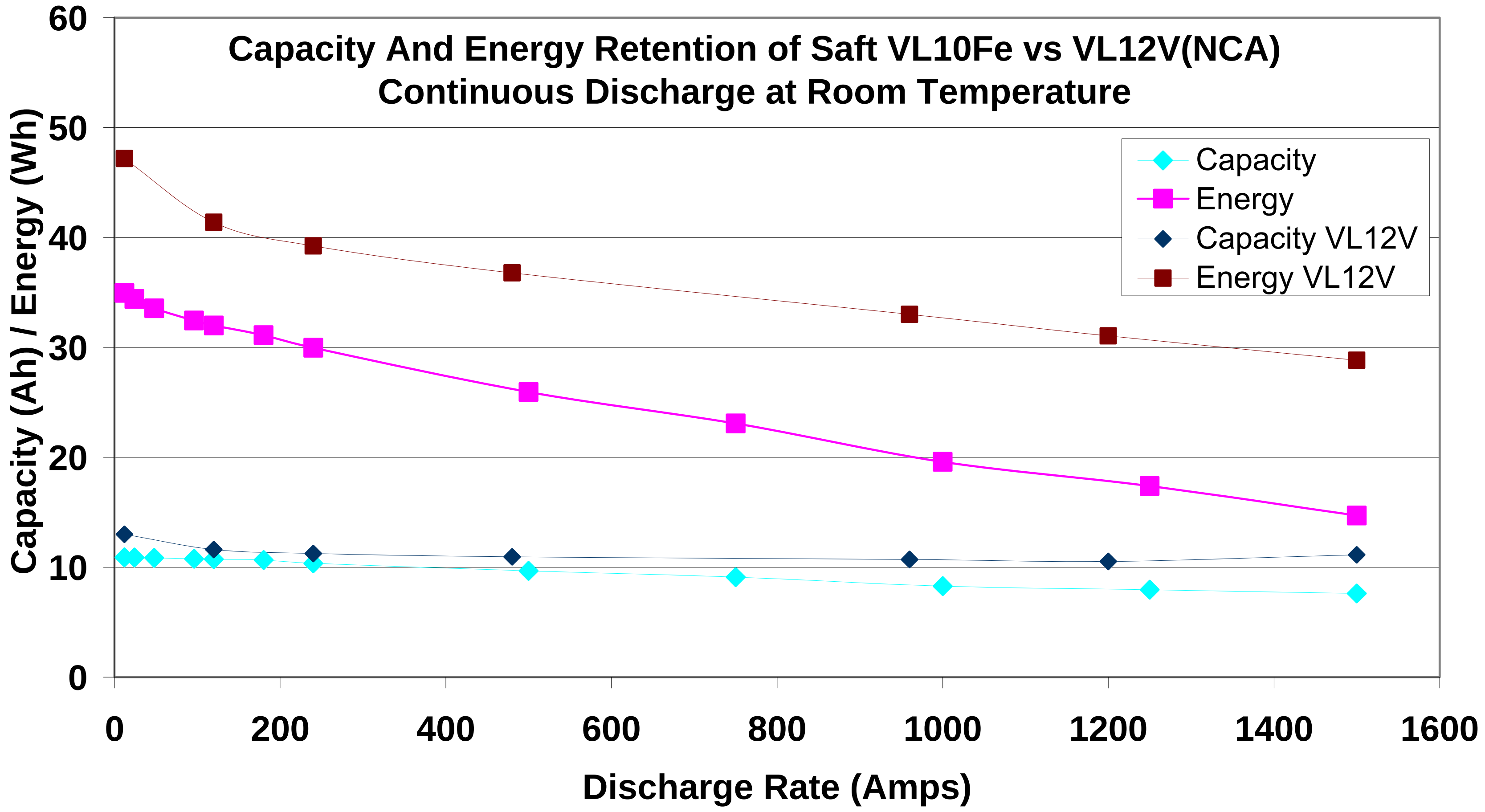




Total Energy Delivered Compared to a standard VL12V (NCA cathode):

- **75% of VL12V Energy at 12Amps** **50% of the VL12V Energy at 1500Amps**

LiFePO$_4$ Development



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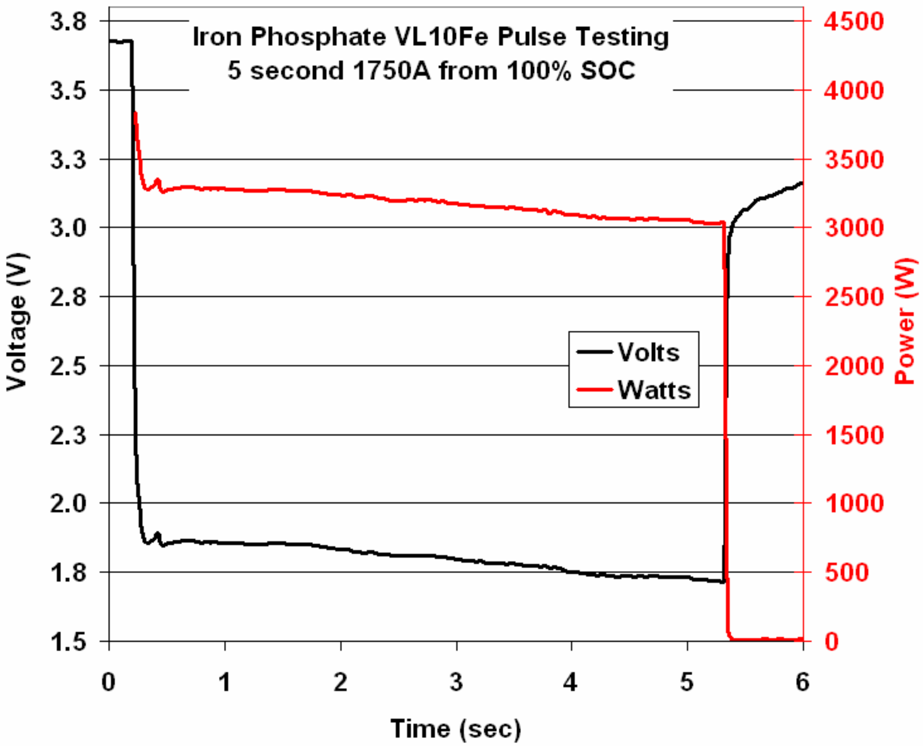
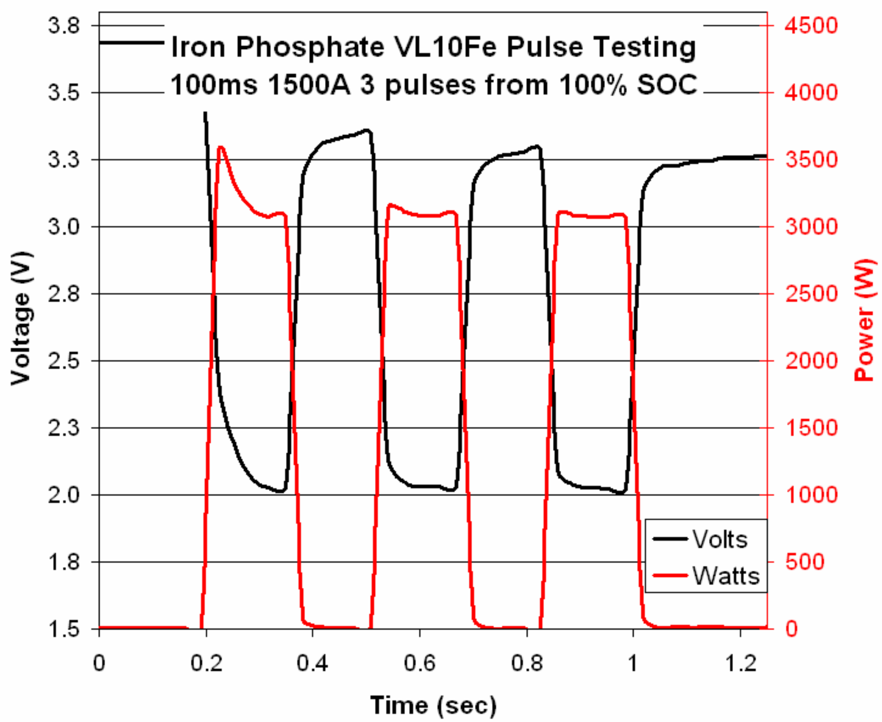
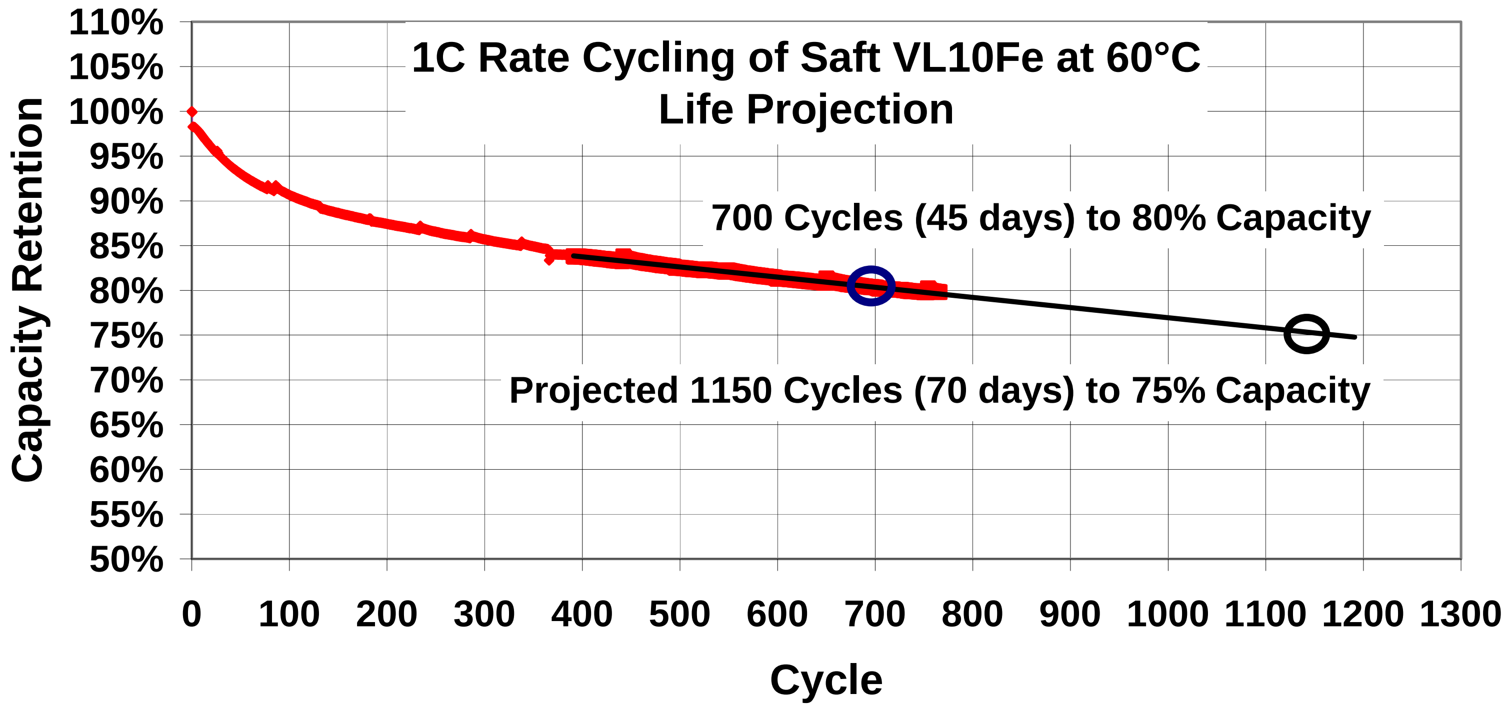
- **Pulse testing - 5 sec 1750A**

5400W/kg → SECOND MOST POWERFUL CELL AFTER SAFT VL-V CHEMISTRY





LiFePO$_4$ Development



- Calendar life testing is incomplete but expected to be shortened by elevated temperature similar to other Iron Phosphate cells
- Temperatures above 60°C significantly reduce life

LiFePO$_4$ Development

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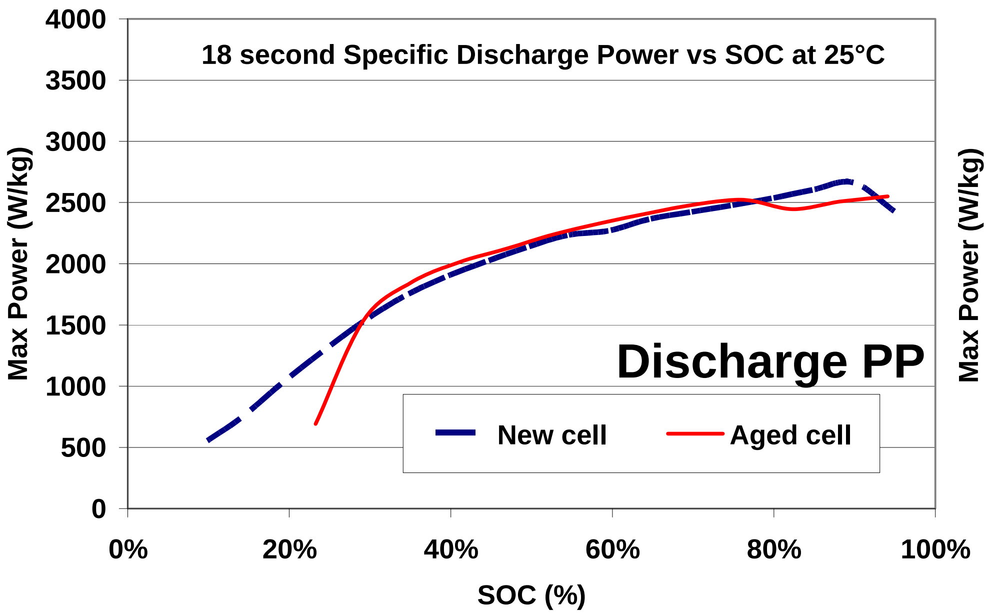
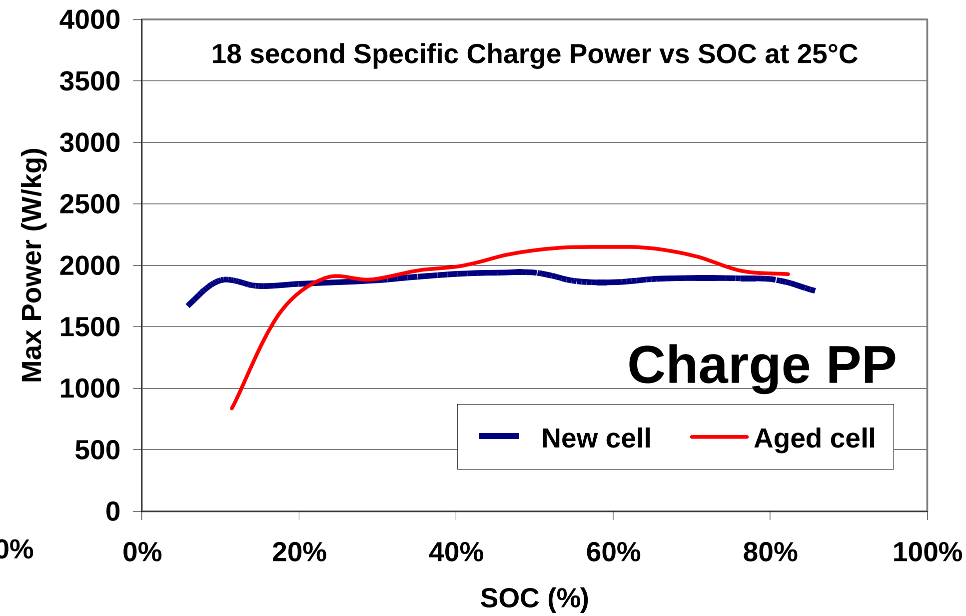
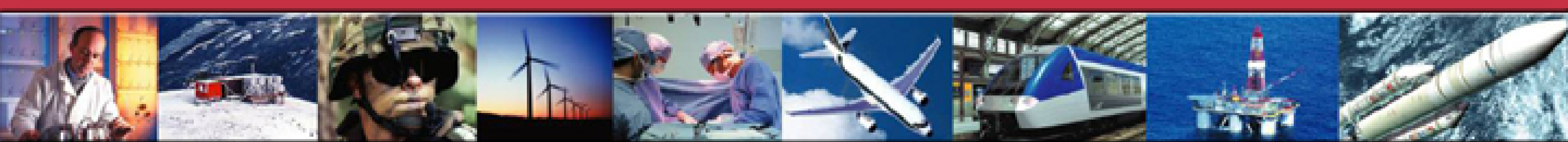
- **Pulse Power retention with ageing**
  - 2500 W/kg 18sec Discharge PP @ (70-100)% SOC & 25°C
  - 1900 W/kg 18sec Charge PP @ (20-80)% SOC & 25° C
  - Nearly no power loss after 700 full cycles @ 1C rate & 60°C







LiFePO$_4$ Development

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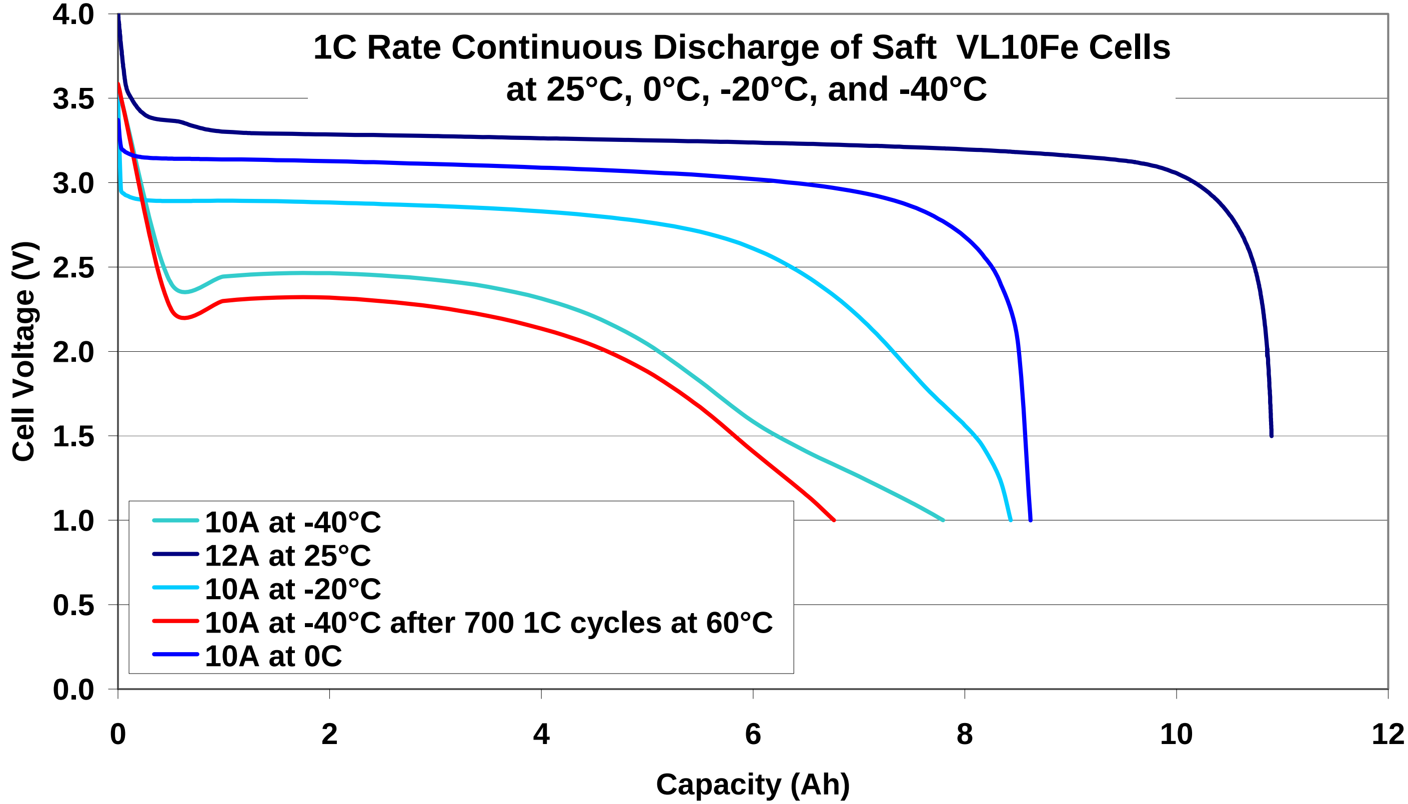

- Low Temperature Performance Needs Improvement

$LiFePO_4$ Development

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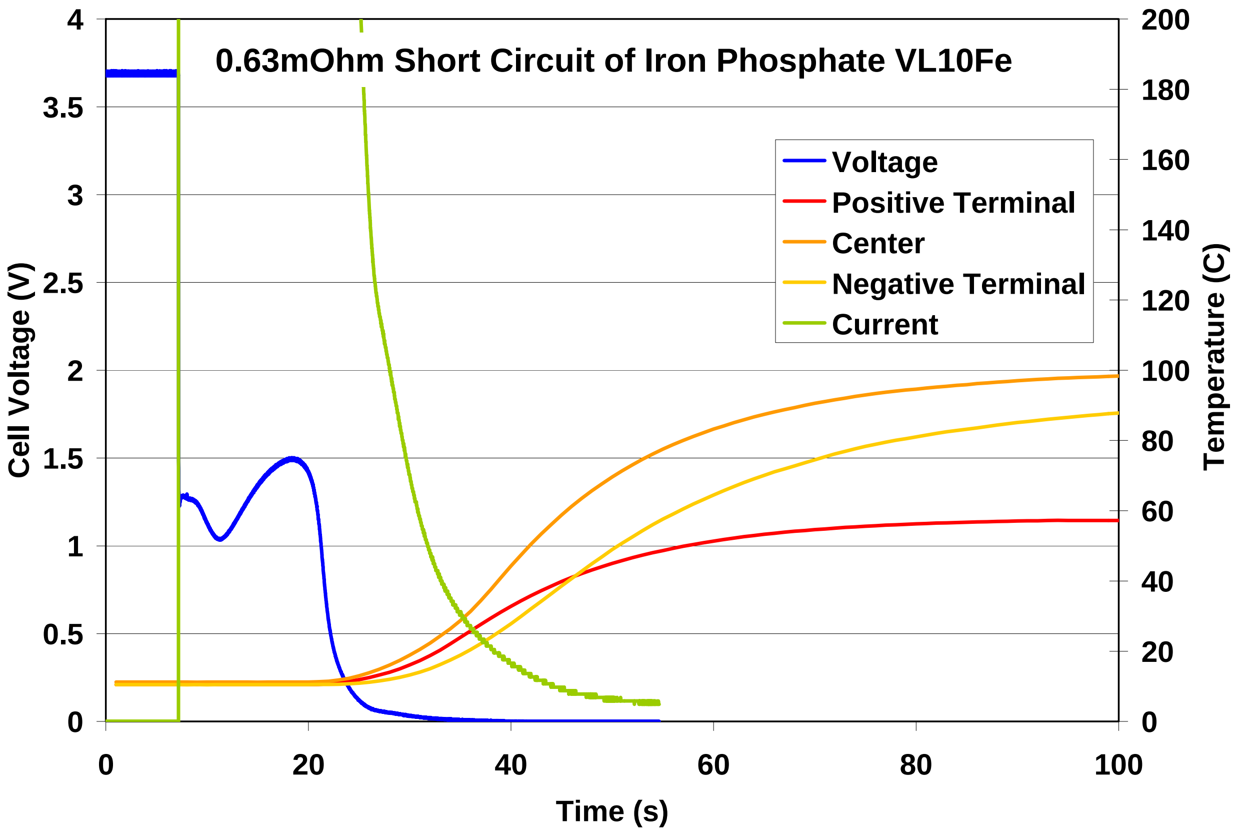
- $LiFePO_4$ cathode: enhanced safety
  - **less lithium excess + reduced oxygen evolution →**
    - **less heat generation + lower energy density → lower temperature rise**

$LiFePO_4$ Development: Safety



0.63 mOhm Short Circuit

- **No event**
- **T<100°C**

LiFePO$_4$ Development: Safety

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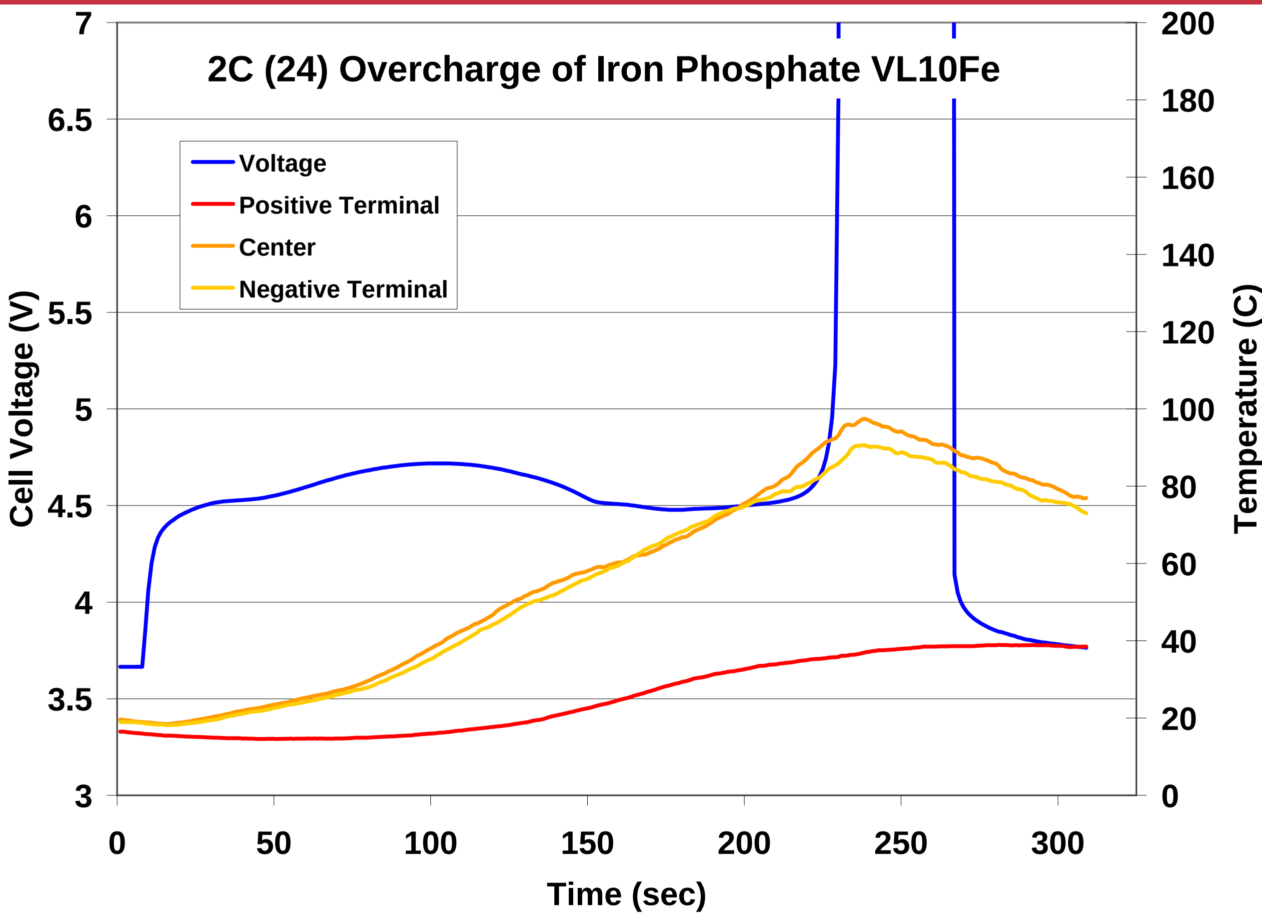


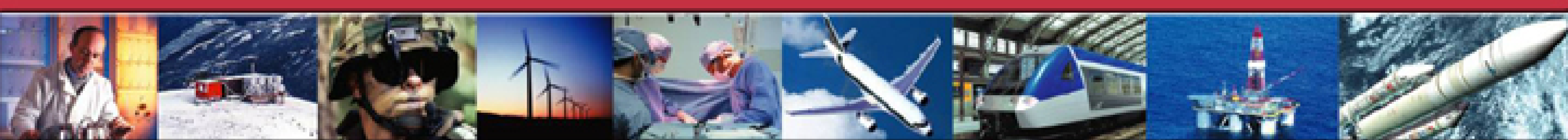
2C (24A) Overcharge

Vented with no smoke & no fire

- **T<100°C**

Conclusion

- Iron Phosphate is suitable for high power applications that require an added level of redundant safety.
- The requirements of the application must be considered as there are tradeoffs in:
  - Lower power & energy
  - Poorer low temperature performance
  - Less robust at high temperature for storage



Four Facilities

North Haven, Connecticut

Valdosta, Georgia

Cockeysville, Maryland

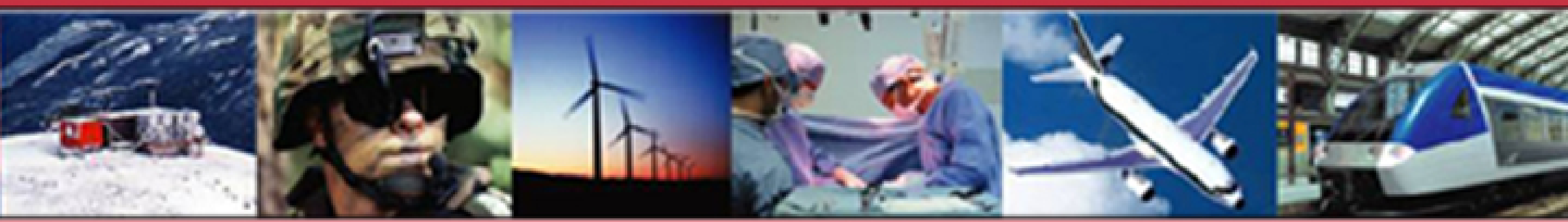
Valdese, North Carolina

The World’s Largest Specialty Defense Battery Manufacturer

The military’s power resource

Discover Saft.

Even if you know us already.



Warfighting in a Climate Warming World - Implications for U.S National Security Policies

2007 Joint Service Power Expo
Power and Energy Independence for the Warfighter

Hon. Philip Coyle
Senior Advisor
World Security Institute

Hon. Martha Krebs, Ph.D
Deputy Director for R&D
California Energy Commission

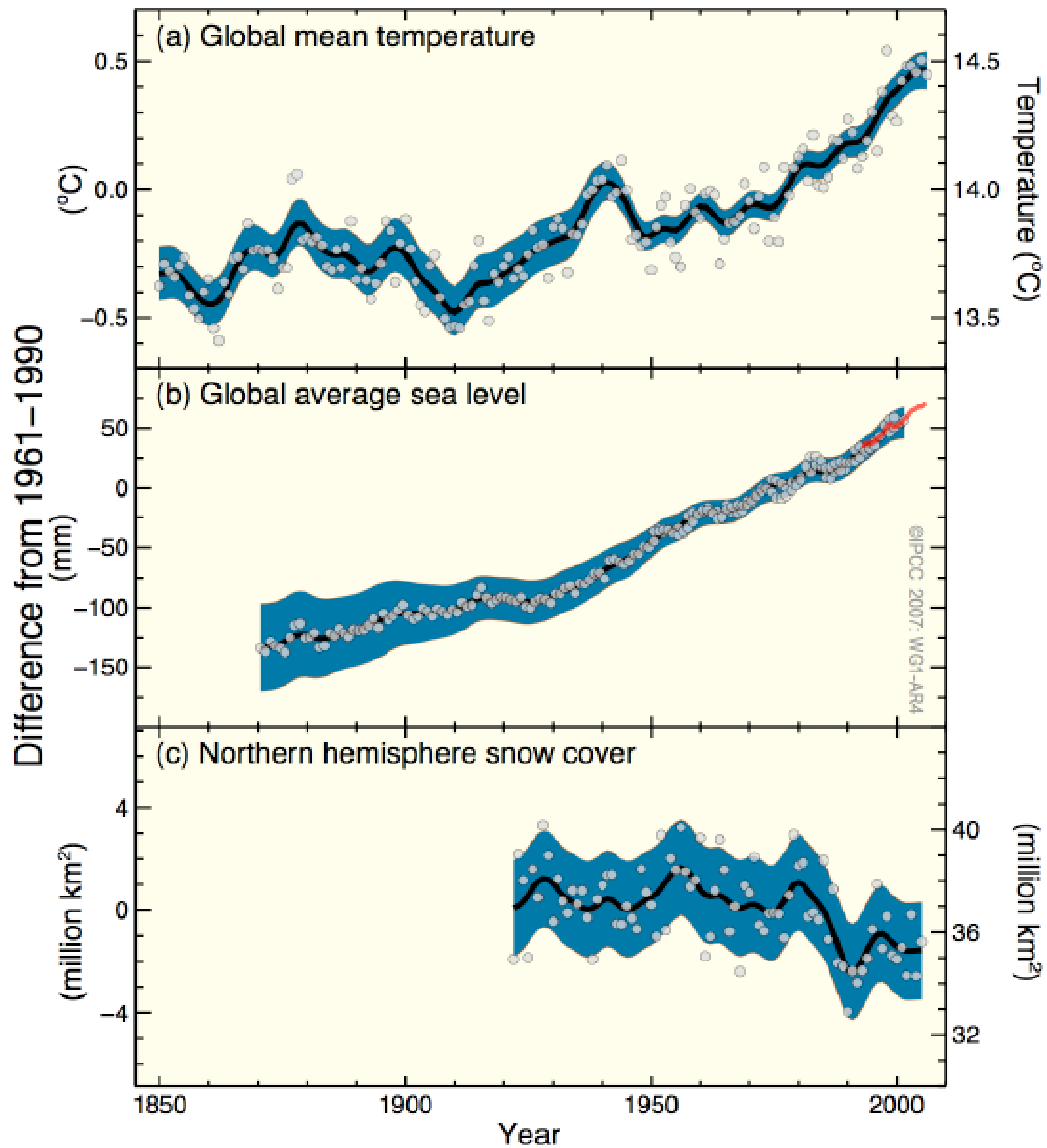
April 25, 2007

CDI | CENTER FOR DEFENSE INFORMATION


Positive proof of global warming.
18th Century
1900
1950
1970
1980
1990
2006

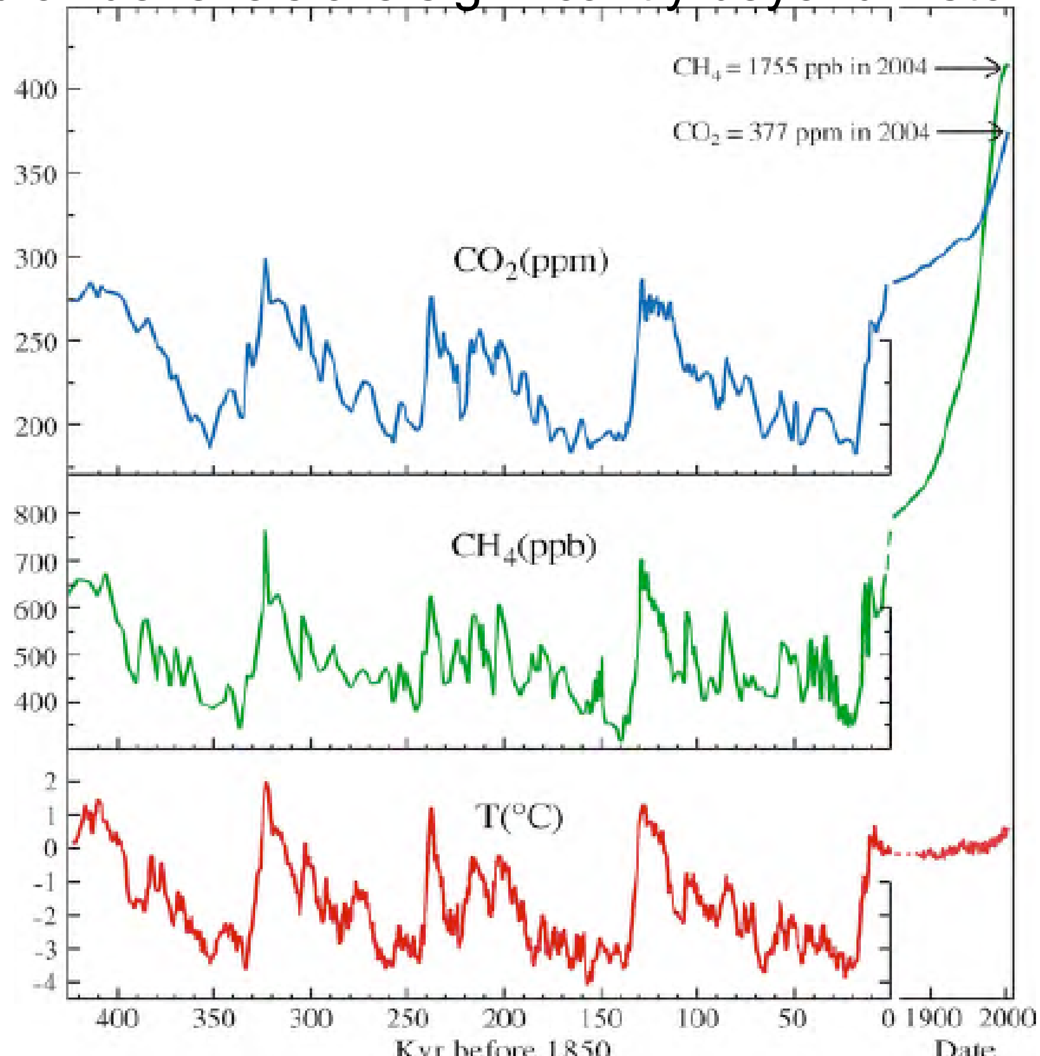
In the last 150 Years

- Temperatures have risen
- Sea level is higher
- Snow cover is down



In the last 400,000 years

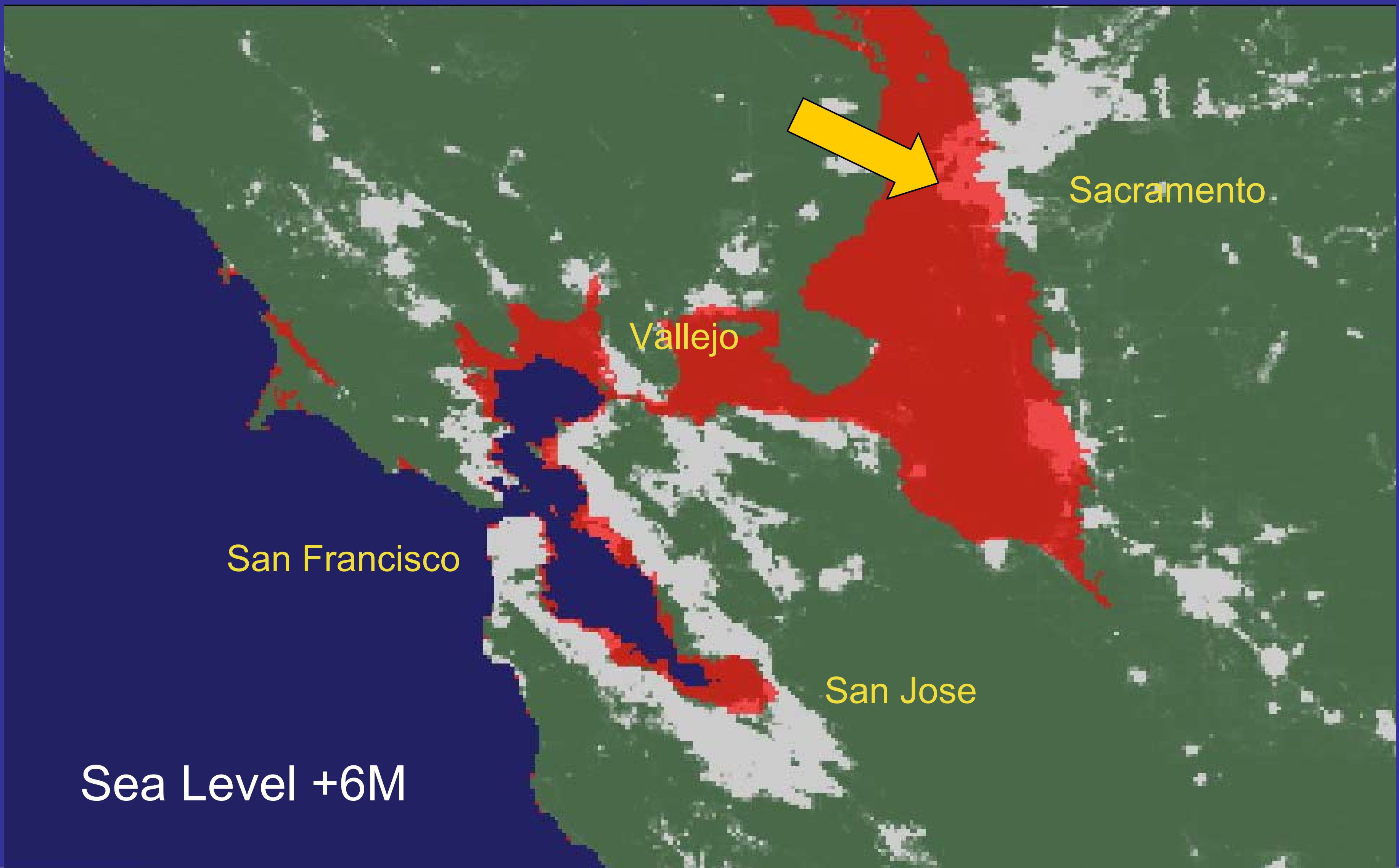
- Temperatures are at the upper end of historical variability, but
- Carbon dioxide levels are significantly beyond historical levels



CO2,CH4 and estimated global temperature (Antarctic ΔT/2 in ice core era) 0 = 1880-1899 mean.

Source: Hansen, *Clim. Change*, **68**, 269, 2005.

You think Katrina was bad; Here's where I Live under a 6m storm surge!



Report of the United Nations Intergovernmental Panel on Climate Change

Fourth major assessment since 1990

2500+ scientific expert reviewers

800+ contributing authors and

450+ Lead authors from

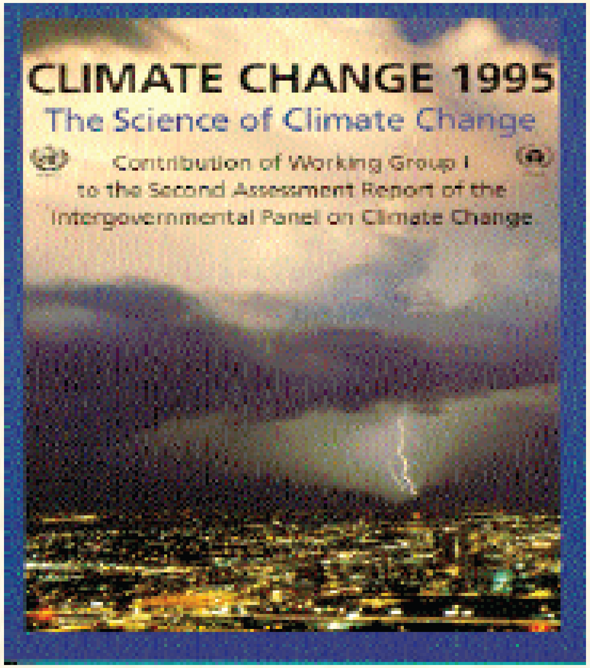
130+ countries

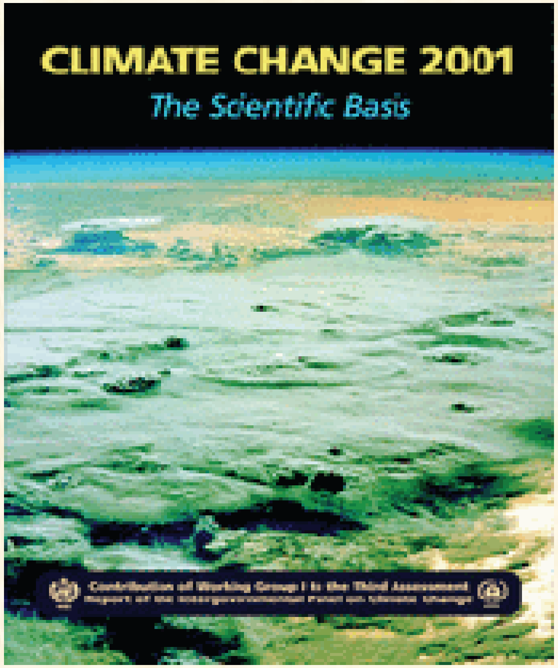
6 years work

4 volumes

1 report

Detection and attribution conclusions of IPCC Second and Third Assessment Reports (1995, 2001)





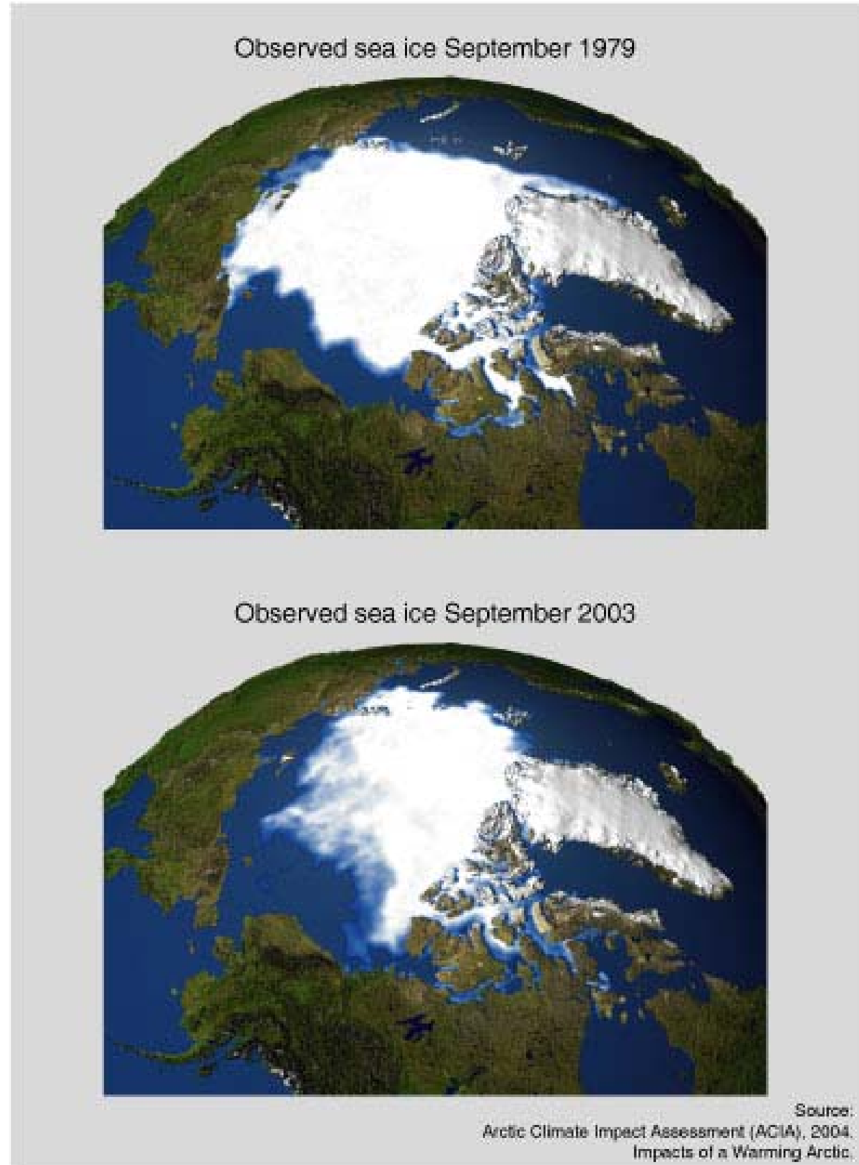
"The balance of evidence suggests a discernible human influence on global climate"

"There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities"

Climate Change 2007: The Physical Science Basis
Working Group I Contribution to the
IPCC Fourth Assessment Report

Direct Observations of Recent Climate Change

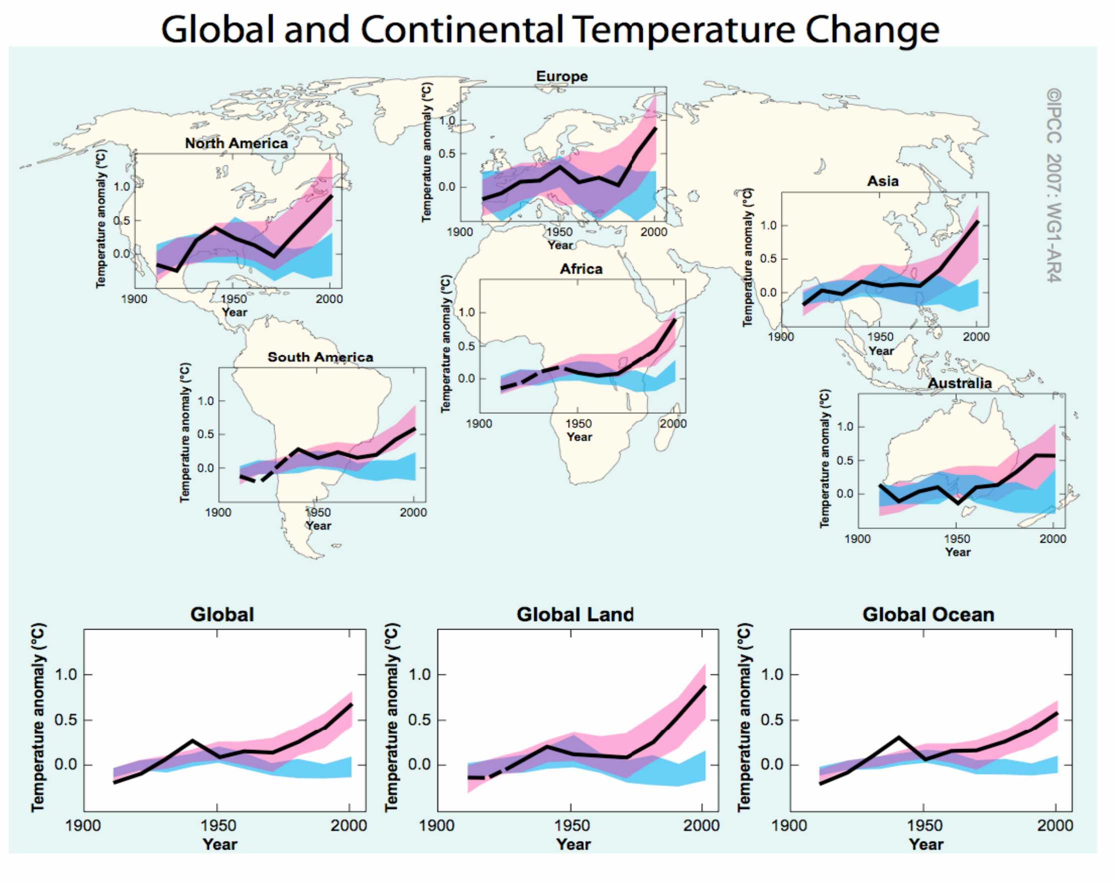
Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global mean sea level.



Climate Change 2007: The Physical Science Basis
Working Group I Contribution to the
IPCC Fourth Assessment Report

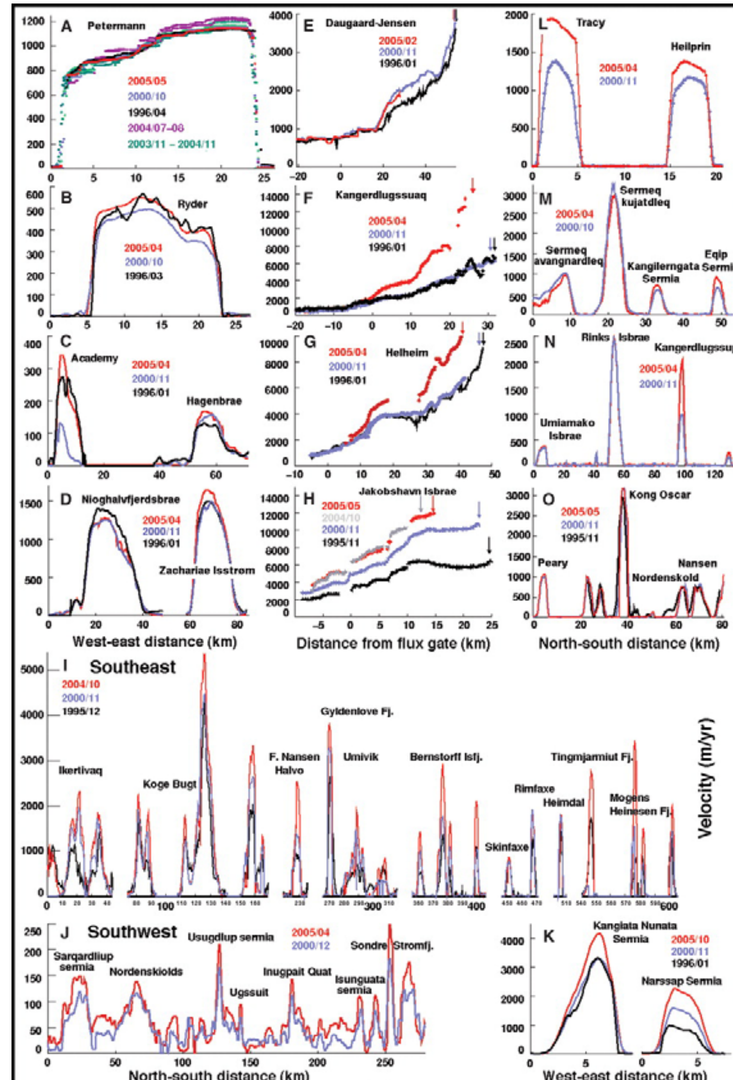
Human and Natural Drivers of Climate Change

The understanding of anthropogenic warming and cooling influences on climate has improved since the Third Assessment Report (TAR), leading to very high confidence that the globally averaged net effect of human activities since 1750 has been one of warming, with a radiative forcing of +1.6 [+0.6 to +2.4] W m^{-2}.



Limitations of the UN Study

- Data behind the UN study were frozen two years ago.
- The problem is actually worse.
- Greenland is melting faster than we expected



E. Rignot et al., Science 311, 986 -990 (2006)

Recent DOD Studies

- Defense Science Board Task Force on DOD Energy Strategy. Chartered May 2, 2006.
- National Security and the Threat of Climate Change, The CNA Corporation, Gordon Sullivan, Chair, April 16, 2007.
- Reducing DOD Fossil-Fuel Dependence, JASON, September 2006, JSR-06-135.
- An Abrupt Climate Change Scenario and Its Implications for United States National Security, Peter Schwartz and Doug Randall, Global Business Network, October, 2003.

What's the Threat?

- Cost of fuels
- Availability of fuels
- Operational flexibility
- Deployability
- Strategic Balance
- Sustainability

Yes, but What's the <u>Real</u> Threat?

The Good News

- No extended world-wide shortage of fossil fuels for ~ 25 years.
- DOD fuel consumption is < 2% of total U.S. domestic fuel consumption.
- DOD fossil fuel spending is only 2.5-3% of the national defense budget.

The Bad News

- The world will need as much oil in the next 25-30 years as has been produced over the last 150 years.
- DOD fuel consumption is 93% of U.S. Government use.
- Mobility fuels = vast majority of DOD fuels use.
- JP-8 cost is up 2.8X since 2004= >$4B/year

More Bad News

- Current logistics supply chain designed when “behind the front lines” meant “safe.” Today = Iraq, IEDs, etc.
- Air-to Air = $20-25 per gallon.
- Army theater = $100-600 per gallon.
- Ethanol and Hydrogen unsuitable?
- But 62% of DOD fuel use is CONUS.

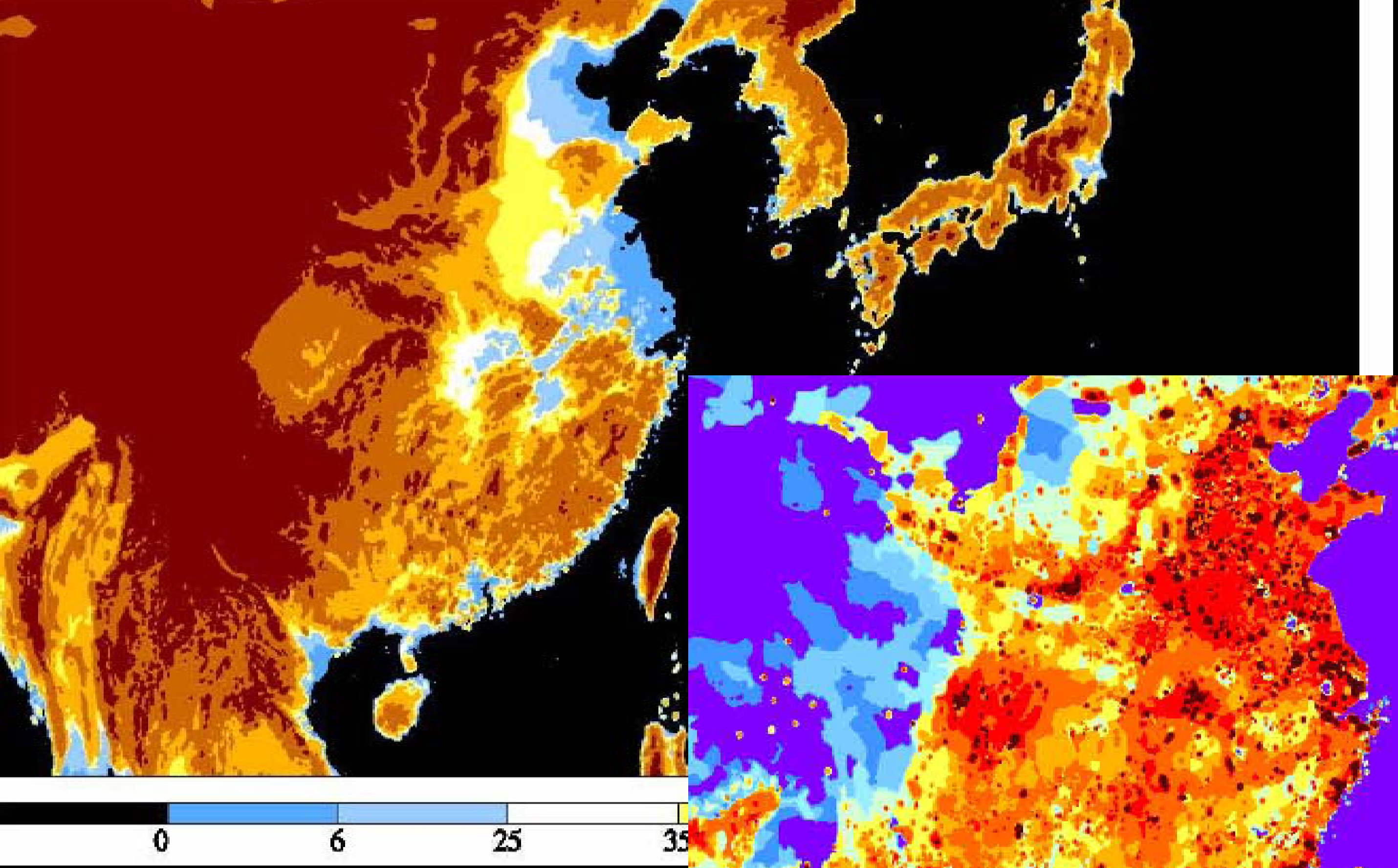
What’s the Real Threat?

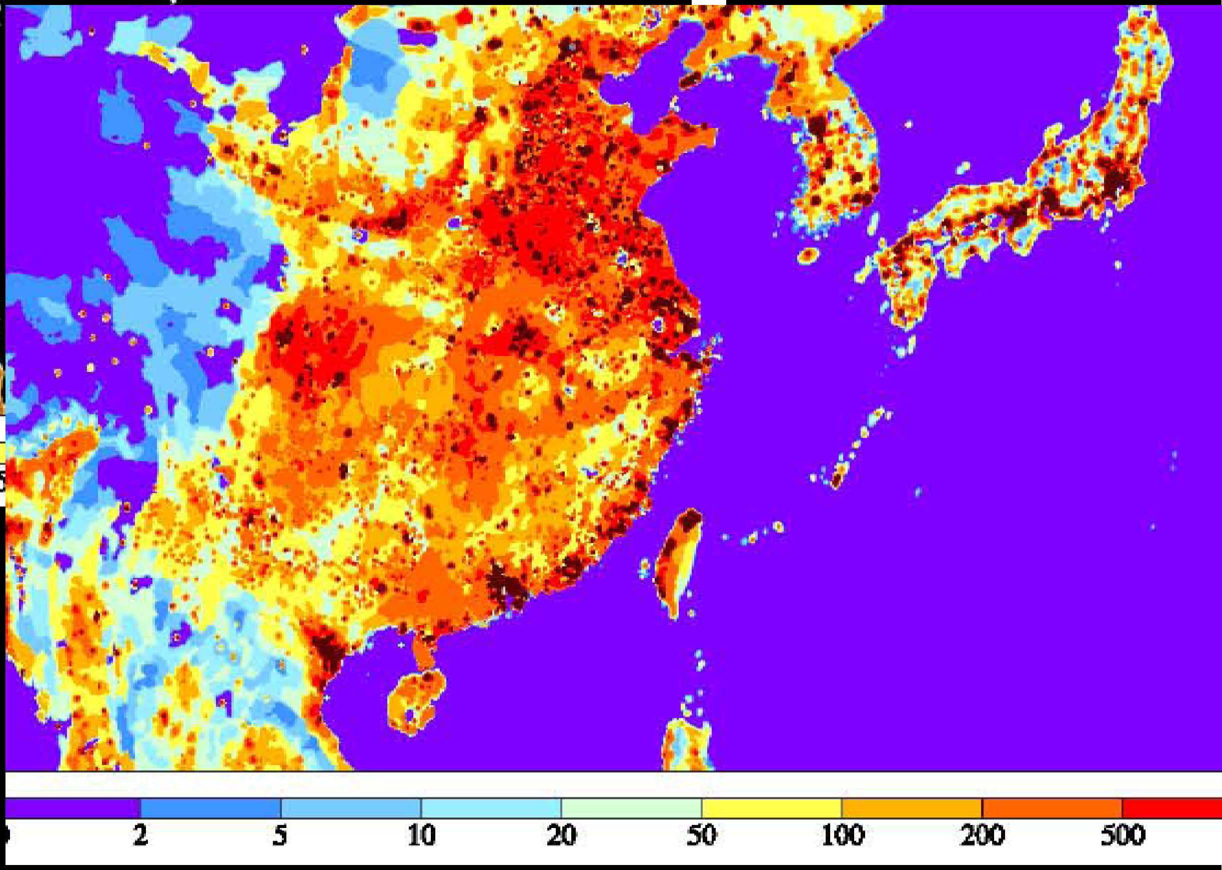
- Massive population displacements due to loss of land mass.
  - China, India, Bangladesh, Myanmar
  - Persian Gulf
  - Vietnam, Thailand
  - Indonesia, Phillipines
- Impacts on water availability, growing seasons
- Geographical range of infectious disease

Complete melting of Greenland glaciers = 6.55 meter sea rise

Complete melting of all glaciers = 80.32 meter sea rise

USGS Fact Sheet 002-00 January, 2000





93 million Chinese (~7%) at risk in 6m storm surges.

Loss of Land Mass ~ China

- 93 million people in China could be displaced by a 6 meter sea-level rise.
- In terms of loss of territory, loss of lives, economic disruption, and long term effects, global warming can be compared to nuclear war.

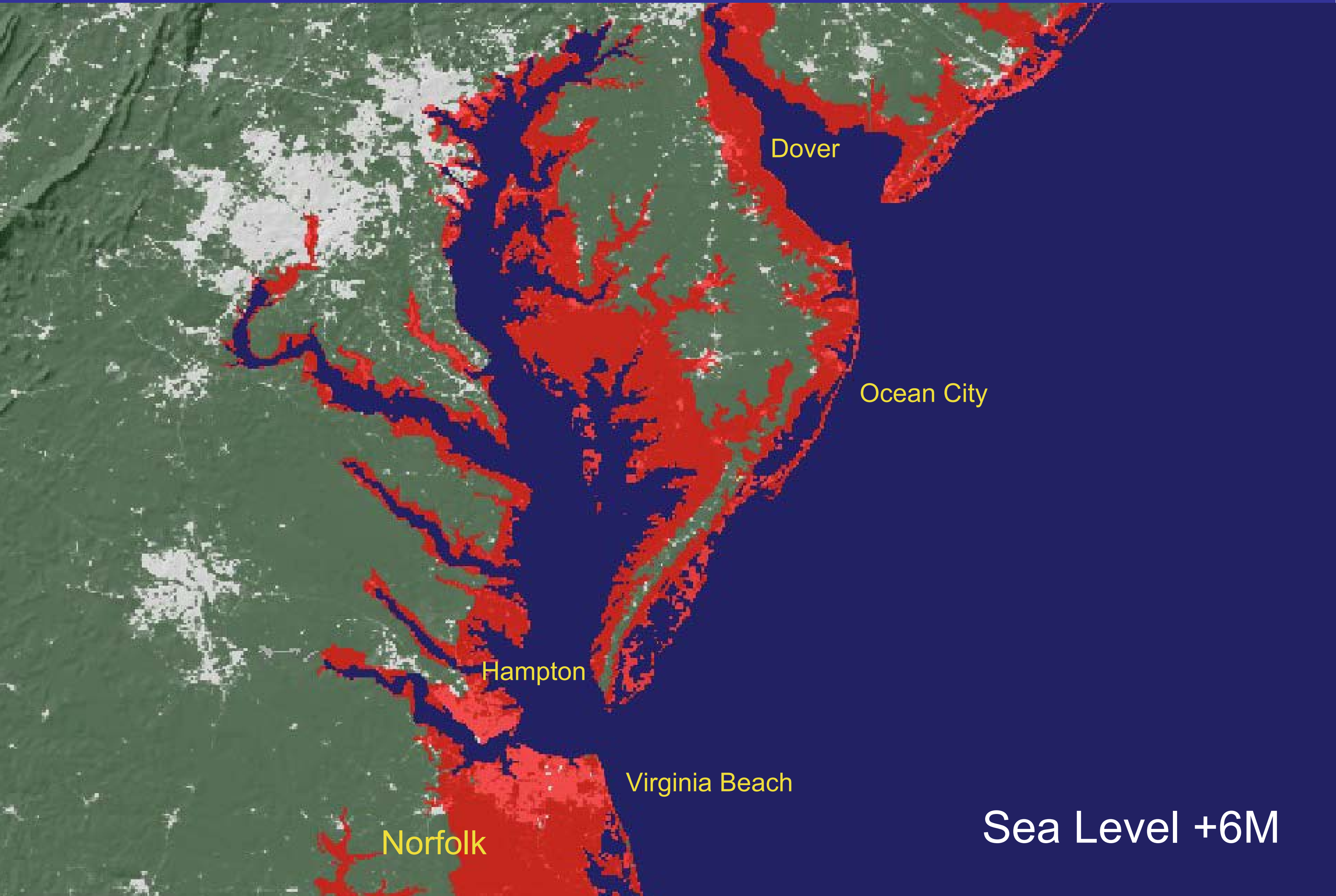
Region (total population in millions, 2000)	**Population Under Water (for given sea level rise)**			
	6m	***25 m***	***35m***	***75m***
United States (283)				
East Coast	9	41	51	70
West Coast	2	6	9	19
China + Taiwan (1275+23)	93	224	298	484
India + Sri Lanka (1009+19)	46	146	183	340
Bangladesh (137)	24	109	117	130
Indonesia + Malaysia (212+22)	23	72	85	117
Japan (127)	12	39	50	73
Western Europe (454)	26	66	88	161

Hansen

Sea-level rise in Regions of Importance to the U.S. Military

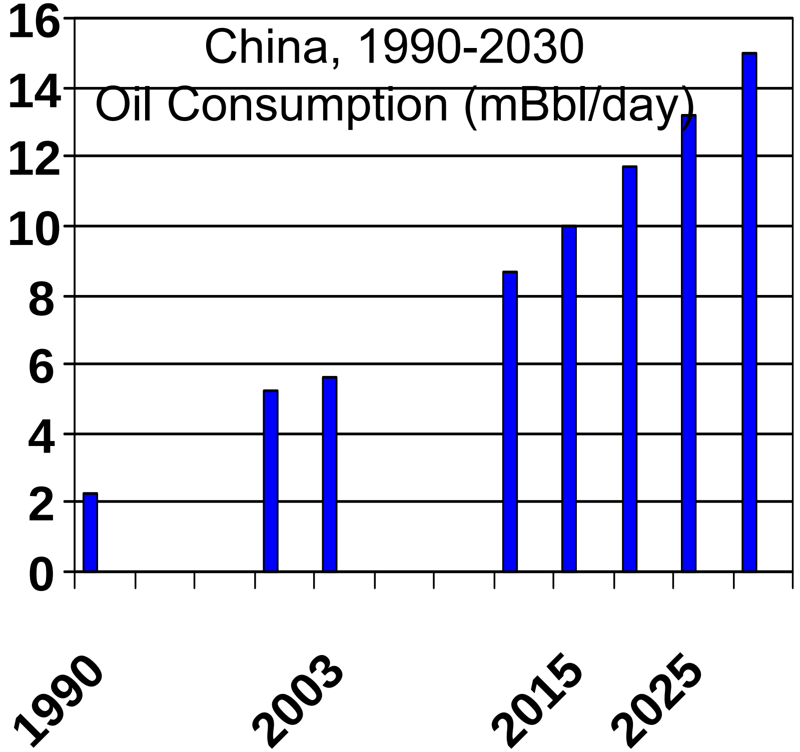
- Norfolk, Virginia
- Florida
- Gulf Coast
- Carolinas
- Hawaii

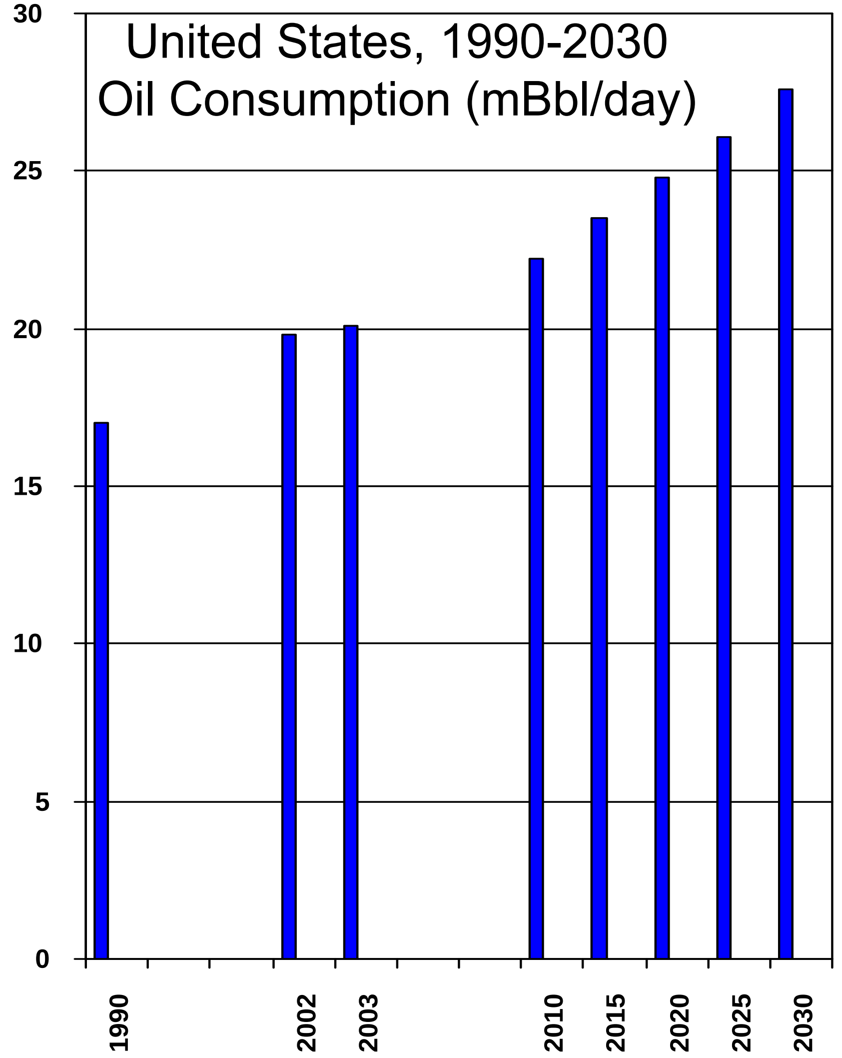

Dover
Ocean City
Hampton
Virginia Beach
Norfolk
Sea Level +1M


Dover
Ocean City
Hampton
Virginia Beach
Norfolk
Sea Level +6M

Strategic Oil Supply

EIA International Energy Annual 2006
Reference Case





Expectations

- The U.S. Military as a microcosm of U.S. society
- Preserving the American way of life; Preserving American values
- Domestically, American support of the U.S. Military depends on consistency with U.S. values.

Expectations

- The realization of climate warming and its actual early physical manifestations will come to have an impact on the U.S. military as well as on other sectors of American endeavor.
- While in battle the U.S. military could well be exempted from the constraints of climate warming, but during periods of low intensity conflict or relative peace, the U.S. military could well be expected to do its share to reduce these impacts.

National Security can drive innovation in energy supply

An Historical Precedent

The U.S. Synthetic Fuels Corporation was created as an amendment (January 15, 1979) to the Defense Production Act of 1950

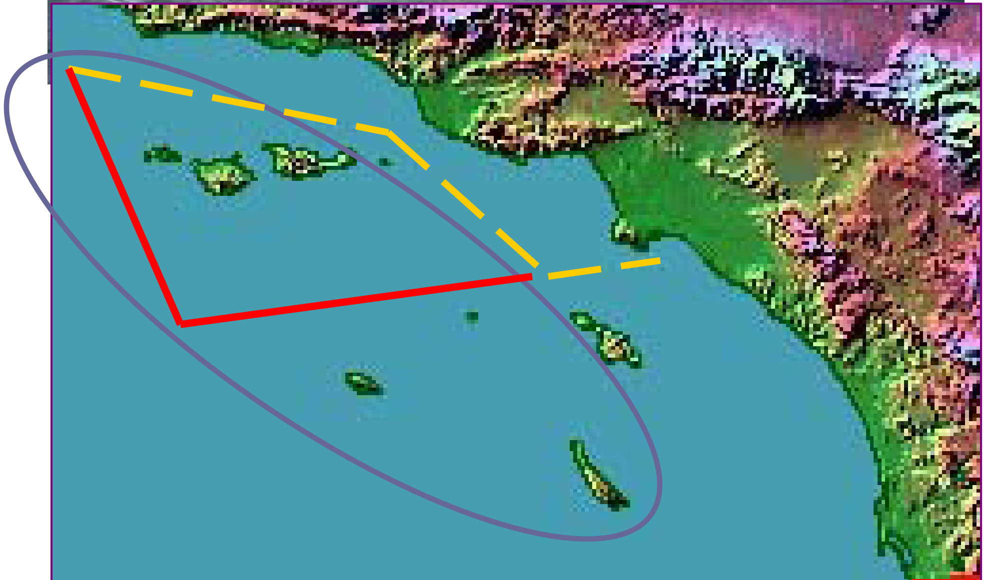
What the U.S. Military is Already Doing

- Army
- Navy
- Air Force
- Marines

Ft. Bliss Ethanol Pump

M-13 SIP ISSUE
(Pt Mugu Ship Channel)

- **Feb 1998 Navy proposal to establish working group to study speed reduction as alternative to moving channel.**
  - **CARB establishes working group(June 1998) Participation by Navy, Shipping Industry, Ports, USEPA**
- **Dec 2000 Final Report**
  - **Relocated commercial channel increases estimated 2010 SIP NOx pollution by 1.3 tons per day (greater steaming distance of relocated channel)**
  - **Estimated 2010 SIP NOx reductions ranging from 3.9-10.7tons per day from speed reduction in existing channel**
  - **All exceed M-13 target and are feasible for shipping industry**
- **Marine vessel emission reduction/Navy operations can co-exist**



Source: NAVSEA Environmental Presentation

“Unleash us from the tether of Fuel.” Lt.Gen. James Mattis, USMC

“Commit to hybrid electric architecture for Tactical Wheeled Vehicles (TWV)”

“Long term commitment to manufactured liquid hydrocarbon fuels from domestically abundant feedstocks.”

Key Actions, Naval Research Advisory Committee Report, April 2006.

“Flying Out In Front: *The Air Force Is Taking The Lead On Synthetic Fuel; Will You Follow Us? Asks Michael Wynne*”

Dallas Morning News January 27, 2007 Pg. 21

Strategic Supply

Oil prices and availability are still being determined by geo-politics, especially Middle Eastern politics, not raw supply.

Saudi Arabia can and does dampen Iranian adventurism by reducing the price of oil.

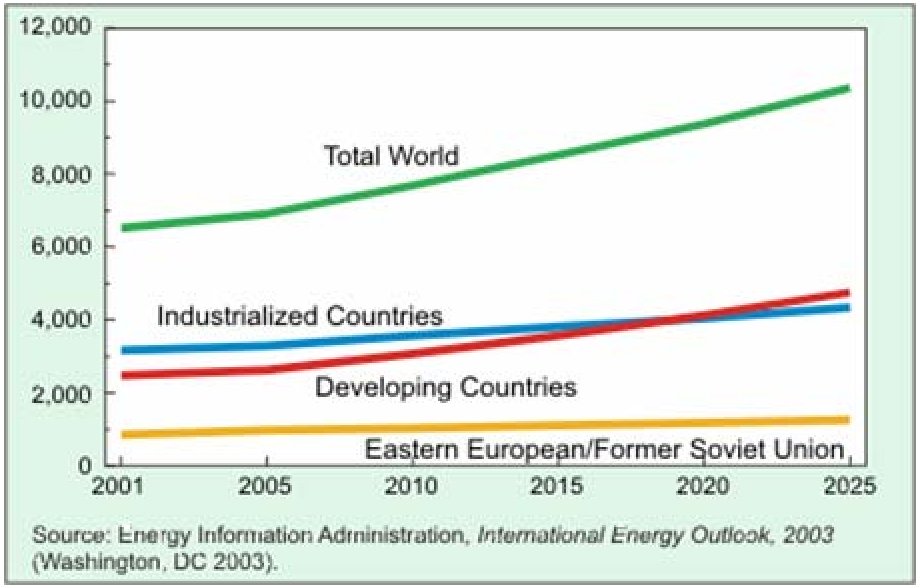
“Yes, some time next decade demand may indeed start to bump up against supply, but the price of oil today is as much political as it is supply and demand.” John Mauldin, 1-12-07

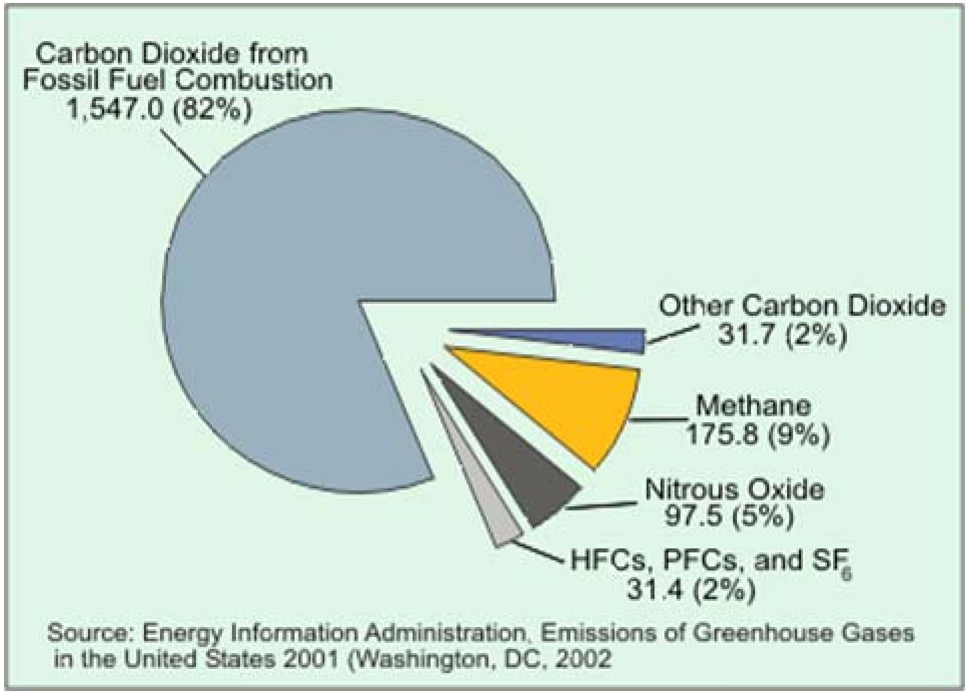
Strategic Supply is Important

- But coal to liquids makes carbon problem worse.
- 50% Coal-To-Liquids efficiency leads to 2X more CO_2 emissions than from petroleum diesel.
- Must be coupled to Carbon Capture and Storage, e.g. carbon sequestration ~ injecting CO_2 into the ground.
- Large scale demo of carbon sequestration, possibly at one or major U.S. military bases.

Carbon, carbon, carbon

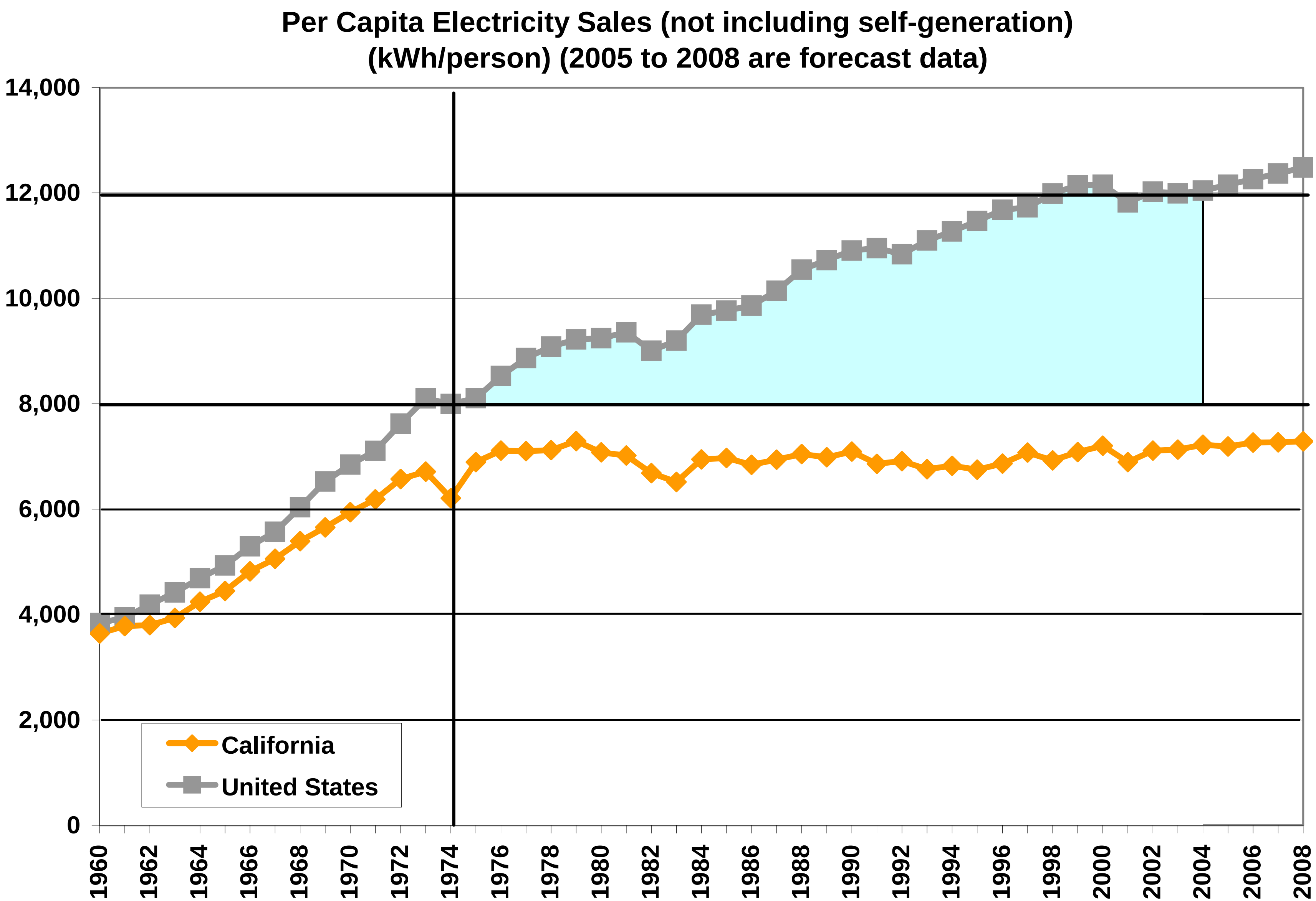
World Carbon Dioxide Emissions by Region, 2001-2025
(Million Metric Tons of Carbon Equivalent)



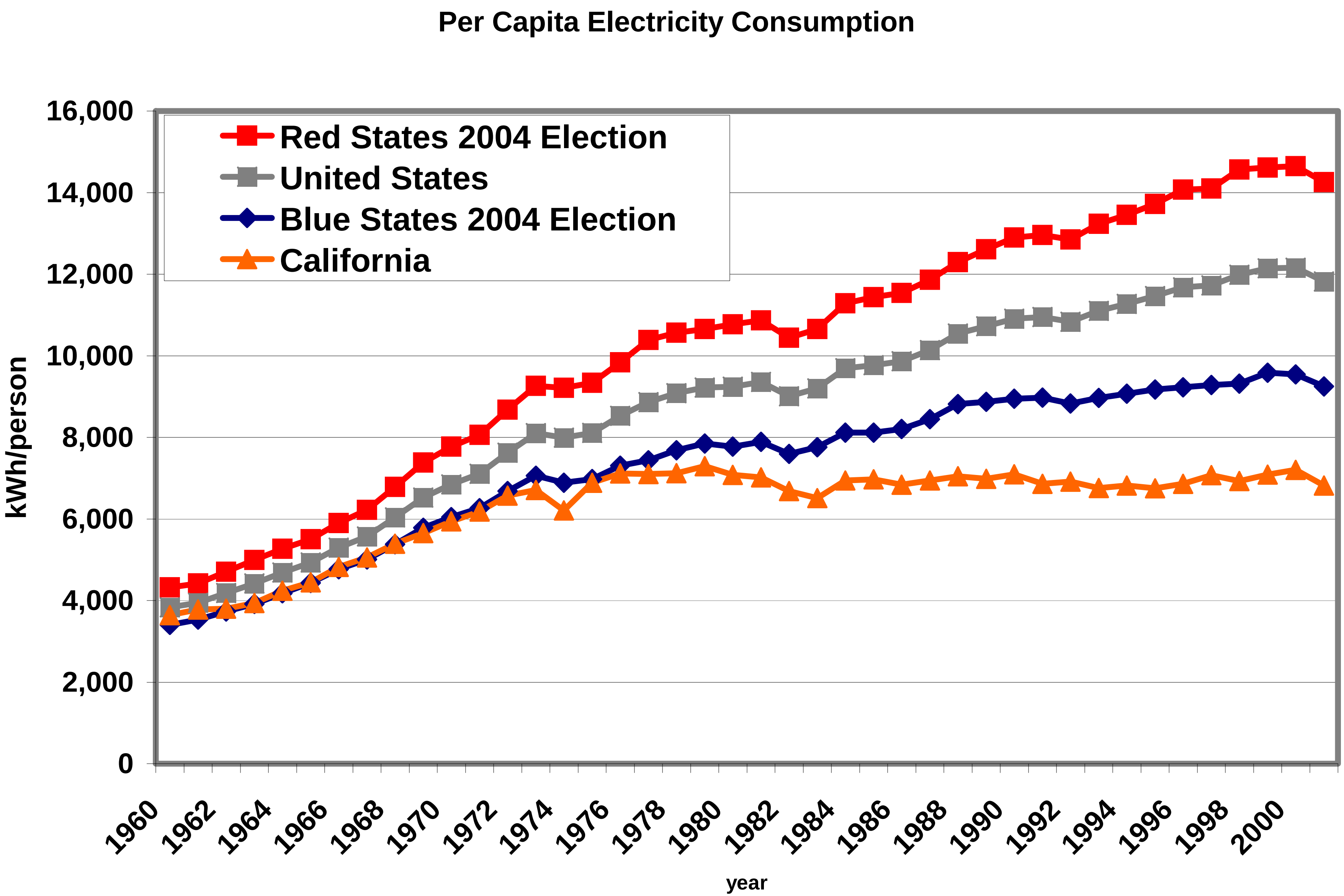


U.S. Anthropogenic Greenhouse Gas Emissions by Gas, 2001
(Million Metric Tons of Carbon Equivalent

California Electricity Consumption



Red States and Blue States



Conclusions

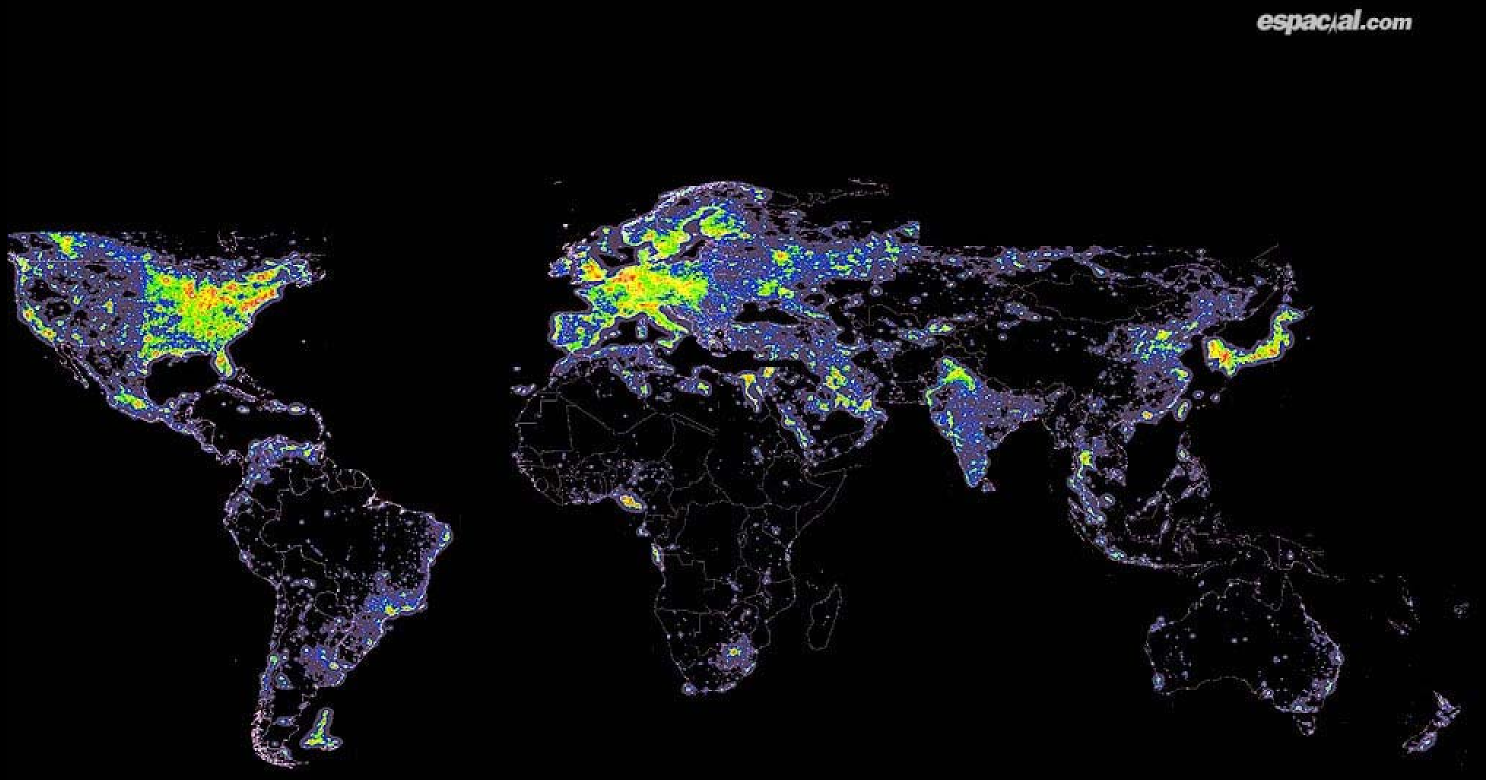
- The cost of fuels is already becoming a burden to the U.S. military.
- Global warming will become an increasing factor in U.S. military planning.
  - DSB Study
  - CNA Study
  - Global Business Network study
- To make a difference, reducing carbon emissions will be key.

Backup slides

Sustainability ~ a Military Definition

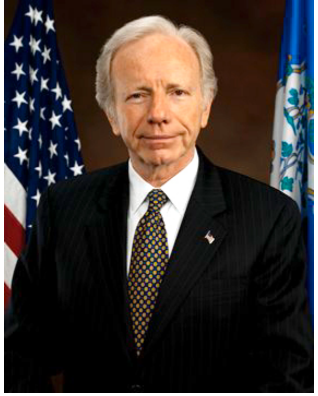
- “The ability to maintain the necessary level and duration of operational activity to achieve military objectives.
- Sustainability is a function of providing for and maintaining those levels of ready forces, materiel, and consumables necessary to support military effort.”

Sustainability is Development that meets the needs of the present without compromising the ability of future generations to meet their own needs. 1987 – World Commission on Environment and Development (the Brundtland Commission)



Loss of Land Mass ~ China

- Western China is not under government control like the eastern and coastal regions of China.
- Western China lives as though the central government does not exist.



Senator Joseph I. Lieberman

- Still, it is my strong hope that having addressed issues of conventional energy supply through this legislation, we will turn, in the very near future, our urgent attention to the most pressing issues - the clear and inextricable linkage between energy supply and national security, the resulting urgent need for aggressive development of a portfolio of alternative and renewable fuels and conservation strategies, and the need to take comprehensive steps to set mandatory caps on greenhouse gas emissions. Solving these problems – and soon – is a responsibility that we have to today's public as well as our children and grandchildren, an obligation that we will not have fulfilled when this legislation passes. - *July 29, 2005*

Senator John McCain

- Global warming is a serious threat. There is overwhelming evidence that increasing amounts of carbon dioxide and other greenhouse gases are heating up the Earth's climate and that inaction could be disastrous. - January 8, 2003

- The status quo is a strong and stubborn force. People and institutions are averse to change, even when that change is critical for their own well-being, and that of their children and grandchildren. If the scientists are right and temperatures continue to rise, we could face environmental, economic, and national security consequences far beyond our ability to imagine. If they are wrong and the Earth finds a way to compensate for the unprecedented levels of greenhouse gases in the atmosphere, what will we have accomplished? Cleaner air; greater energy efficiency, a more diverse and secure energy mix, and U.S. leadership in the technologies of the future. There is no doubt; failure to act is the far greater risk.– January 30, 2007

POWER GENERATION LESSON LEARNED OIF 5-07

MSgt Dickson

Ist Marine Expeditionary Force Headquarters Group

Engineer Chief

INTRODUCTION

- Issues / Dilemmas encountered
- Selecting Commercial Generators
- Purchasing / Contracts
- MEF Emergency Pool
- Reserve Pool

ISSUES/ DILEMMAS

- Insufficient quantity of tactical generators.
- Continuous increase in power requirements for bases.
- Vendors can’t deliver equipment in required time.
- Technical experts not involved in selection process.

ISSUES/DILEMMAS

- Improper generator sizing.
- Ambient temperature.
- Refurbished equipment (pictures).

ISSUES/DILEMMAS

- Multiple manufactured engines and generators.
- Equipment maintenance plan.

SELECTING GENERATORS

- Electrical Assessment (Seabees/Marine/Army).
- Indefinite Delivery Indefinite Quantity (IDIQ).
- Blanket Purchase Agreement.

IDIQ

All new permanent, upgrade, enhancement and renovation base construction projects document shall stipulate use of approved generation systems on all bases, camps or posts in the Al Anbar province of Iraq.

IDIQ

An **I**ndefinite **D**elivery **I**ndefinite **Q**uantity contract will:

- Help stabilize the generator purchase process.
- Simplify the generator purchasing process.
- Shorten the generator delivery time.

IDIQ

- Standardized ordering will encourage standardized base power grids, thereby lowering maintenance (less repair parts for multiple manufactured engines and generators).
- The recommended generator sizes are standard for the industry.

IDIQ (CONT…)

Generators under IDIQ

1) Cummins
2) Caterpillar
3) FG Wilson
4) Marapco

GENERATOR SPECS

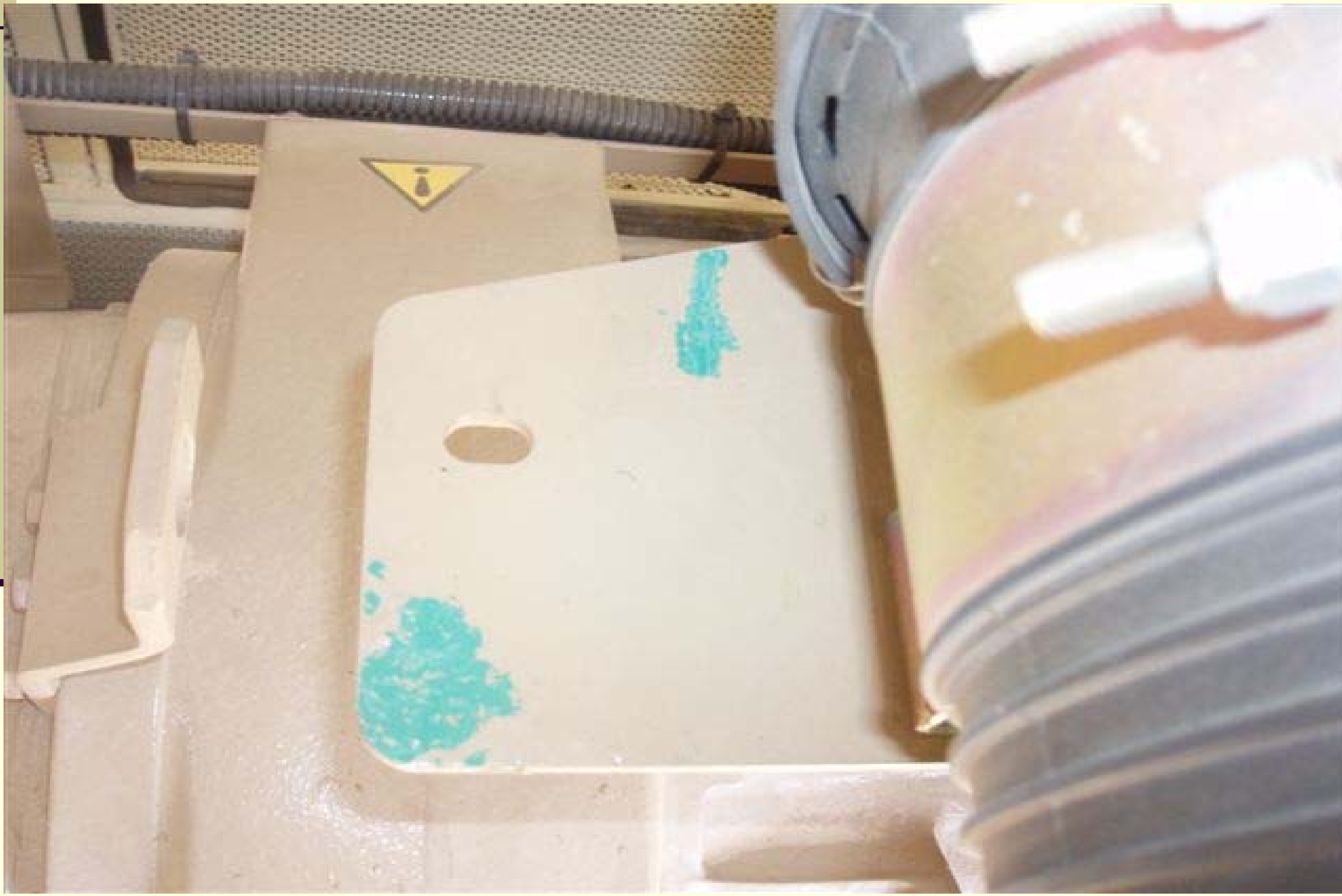
- Prime Power only.
- Capable of operating at temperatures as high as 55 degree Celsius.
- 50 hertz (HZ).
- 220volts low side and 415 volts high side
- Generator must be covered by a weather / sound reduction enclosure including a muffler.
- Secondary containment.

GENERATOR SPECS

- Must include 6 month “push package”.
- Repair parts for diesel motor and generator must be readily available in Iraq, Saudi Arabia, Kuwait.
- Diesel motors must be manufactured by the Cummins and/or Caterpillar and licensed for sale and distribution.
- Diesel motor and generator warranty starts at the time generator has been delivered and accepted.

WHAT WE MUST AVOID

- CONTRACT FOR NEW GENERATORS.
- RECEIVED REFURBISHED GENERATORS.



AC GENERATOR
TYPE
SERIAL NO.
REF. NO.
KVA
RPM
VOLTS
AMPS
AMBIENT TEMP
RATING
AMPS
PHASE
ENCLOSURE
INS. CLASS
EXCITATION VOLTS
WARNING
STAMFORD


2006 6 18


2006 6 18

PURCHASING/CONTRACTS

STEPS

- Validate base/unit requirements.
- **Statement of Work.**
- Contingency Contracting Office.
- Iraqi first concept

MEF EMERGENCY POOL

- Established to provide an emergency generator to units until their primary generator can be repaired.
- Located in two location to better support Coalition and Iraqi Security Forces.
- Generators repaired by ARKEL.

MEF EMERGENCY POOL

- Generators for pool are new or repaired generators from bases not maintained by Kellogg Brown and Root and closed bases.

RESERVE POOL

- Used to fill new power requirements aboard coalition bases.
- List supplied by KBR of available Commercial Generators.
- Saves millions and prevents unnecessary spending.

SUMMARY

- Issues encountered.
- Selecting proper generators to meet requirements.
- Purchasing / Contracts.
- MEF Emergency / Reserve Pool.

Lightweight 2-kW Generator with Integrated Starter Alternator (ISA)

April 25, 2007

2007 Joint Service Power Expo

San Diego, CA

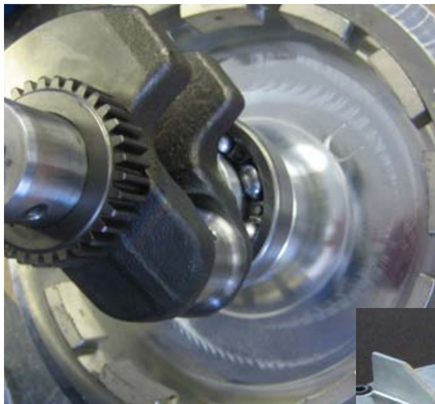
Gregory Cole
gsc@mainstream-engr.com
Mainstream Engineering Corporation
200 Yellow Place
Rockledge, FL 32955
www.mainstream-engr.com

Solutions Through Advanced Technology™
MAINSTREAM
Engineering Corporation

Origin of Mainstream's 2-kW Generator

- Engine Development (1991-)
  - Customer: U.S. Army RD&E Center (Natick)
  - Application: Small, diesel-powered, personal cooling system
- Alternator Development (1994 -)
  - Customer: U.S. Army Aberdeen / OST
  - Application: Miniature, multi-fueled generator
- Results
  - Diesel-cycle is better than Rankine, Stirling, Brayton, and converted spark ignition (gasoline)
  - Mainstream designs and produces integrated, custom machines

Advantages of Mainstream’s 2-kW Generators



Alternator integrated into engine flywheel
- smaller and lighter
- more reliable

Fan integrated into flywheel
- cools power electronics, engine head, oil sump
- runs cooler - increases life and reliability

Custom engine and generator designs
- sized specifically for application
- not just packaging of commercial components

Evolution of Mainstream's 2-kW Generator

48 lbs unmounted

80 lbs fully instrumented and framed

2000-05: SBIR Program to develop generator for Marine Corps' Team Portable Collection System (TPCS)

- Marines wanted 1-kW (min.) 28-VDC generator weighing less than 50 lbs
- Manual recoil starter was desired because external starting power not available for electronic start
- Voltage regulation was not required because external power conditioning system in use
- Result: 2-kW 28-VDC generator

Future of Mainstream's 2-kW Generator

- 2006-07: IR&D
  - Developed patent-pending ISA
  - Developing integral AC inverter with soft-start motor technology
- 2006-2007: Hybrid-Electric Refrigerated Container
  - Mainstream's generator powers a 24-VDC bus and recharges batteries
  - Demo at JOCOTAS next week
- 2007: Cooperative Research and Development Agreement (CRADA) with Army RDECOM
  - Army RDECOM to perform lab tests this summer at Ft. Belvoir

Integrated Starter/Alternator

- Electric start
- Voltage regulation
- Auto-start/stop
- Battery charging circuit
- Allows integration into 24-VDC hybrid electric systems

Army RDECOM Laboratory Tests
(per MIL-STD-705C)

	Physical Characterization
503.1c	Start and Stop Test
601.4b	Voltage Waveform Test (Harmonic Analysis)
601.5	Voltage Waveform Test (Deviation Factor)
602.1b	Voltage Modulation Test
608.1b	Frequency and Voltage Regulation, Stability, and Transient Response Test (Short Term)
610.1b	Voltage and Frequency Droop Test
619.2c	Voltage Dip and Rise for Rated Load Test
640.1d	Maximum Power Test (at 125°F)
650.1b	Ripple Voltage Test
660.1d	Inclined Operation test
661.2c	Sound Level Test
670.1b	Fuel Consumption Test
690.1d	Endurance Test
701.1d	Starting and Operating Test (Extreme Cold Battery Start)
710.1d	High Temperature Test

Physical Characterization

28-VDC Generator Comparison		
Model	MEP-501A	Mainstream MFEG-020028
Dry Weight	124 lbs[1]	93 lbs
Wet Weight	138 lbs[2]	102 lbs
Size	30” (L)[1] 16” (W)[1] 22” (H)[1]	18” (L) 18” (W) 20” (H)

120-VAC Generator Comparison		
Model	MEP-531A	Mainstream MFEG-020120
Dry Weight	143 lbs[1]	118 lbs[3]
Wet Weight	158 lbs[2]	127 lbs[3]
Size	30” (L)[1] 16” (W)[1] 22” (H)[1]	18” (L) 18” (W) 20” (H)

[1] Army TM 9-6115-673-13&P
[2] http://www.pm-mep.army.mil/technicaldata/2kw.htm
[3] Projected based on design

503.1c Start and Stop Test

28-VDC Generator		
	Performance Specification For Military Mobile Power Sources (0.5kW TO 15kW)	Mainstream MFEG-020028
Start Time	Threshold – 5 min Objective – 3 min	3.3 sec
Stop Time	2 min	3.8 sec

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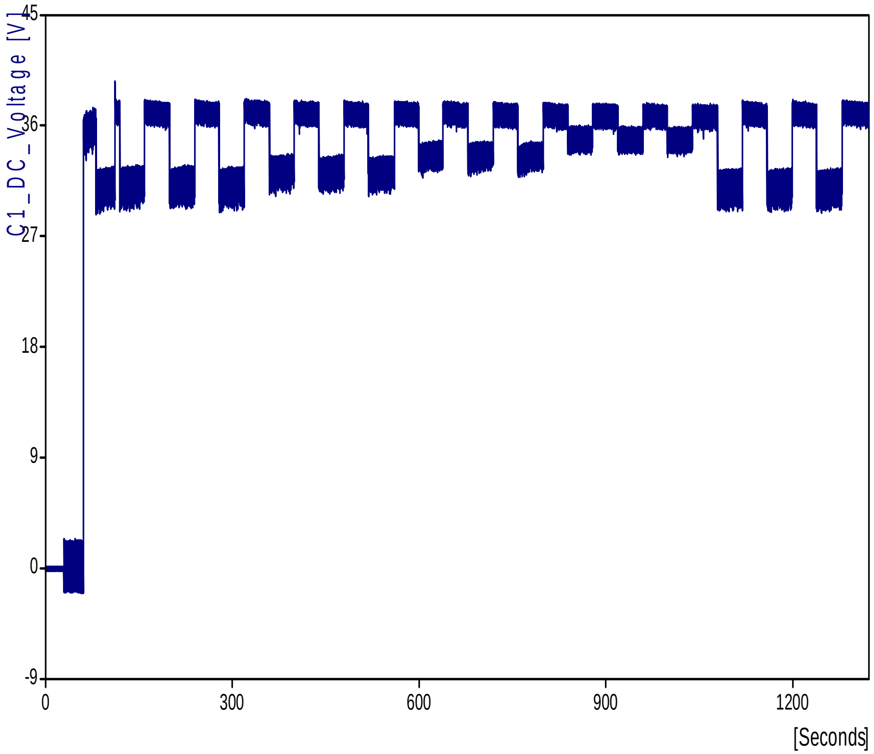
Engineering Corporation

608.1b Frequency and Voltage Regulation, Stability, and Transient Response Test

Prior test results from Army RDECOM with Mainstream's unregulated generator



28-VDC Generator		
	MIL-STD-1332B	Mainstream Unregulated Generator
Voltage - Regulation	4%	20.9%
Voltage – Steady-State Stability	2%	6.6%

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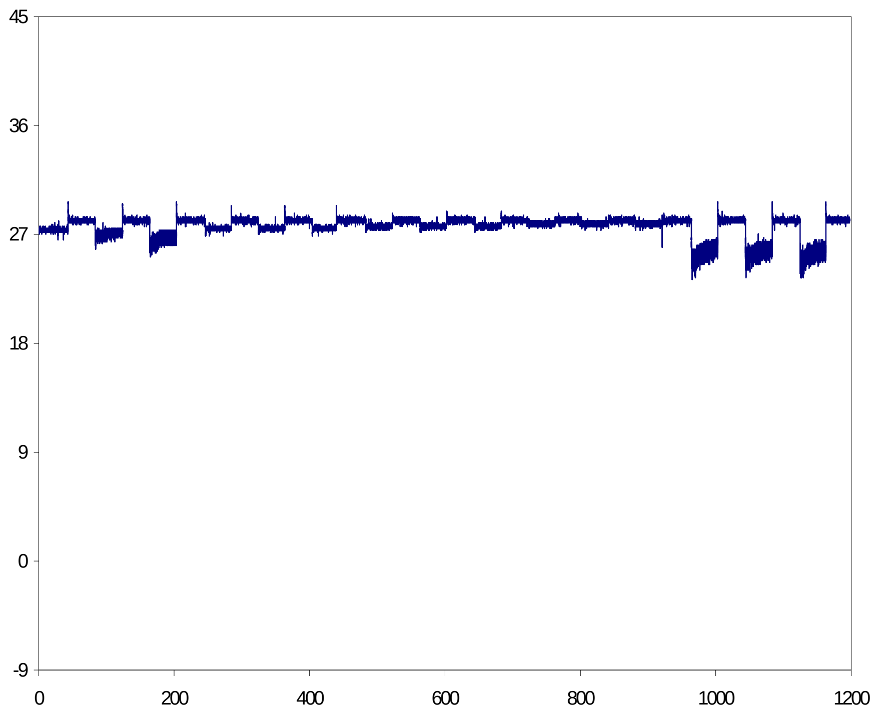
MAINSTREAM
Engineering Corporation

608.1b Frequency and Voltage Regulation, Stability, and Transient Response Test

Current test results with Mainstream's regulated generator with ISA



28-VDC Generator		
	MIL-STD-1332B	Mainstream MFEG-020028
Voltage - Regulation	4%	3.9% @ 100% load* 3.9% @ 75% load 3.4% @ 50% load 2.8% @ 25% load
Voltage – Steady-State Stability	2%	1.1 @ 100% load 1.1 @ 75% load 1.1 @ 50% load 1.1 @ 25% load 1.0 @ 0% load

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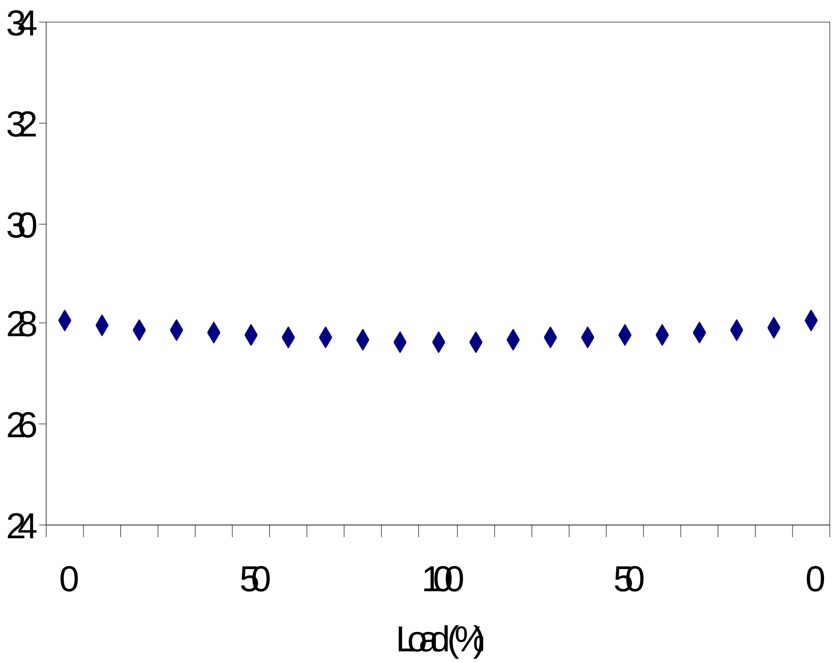
610.1b Voltage and Frequency Droop Test



28-VDC Generator		
	MIL-STD-1332B	Mainstream MFEG-020028
Voltage - Droop	not specified	1.4%

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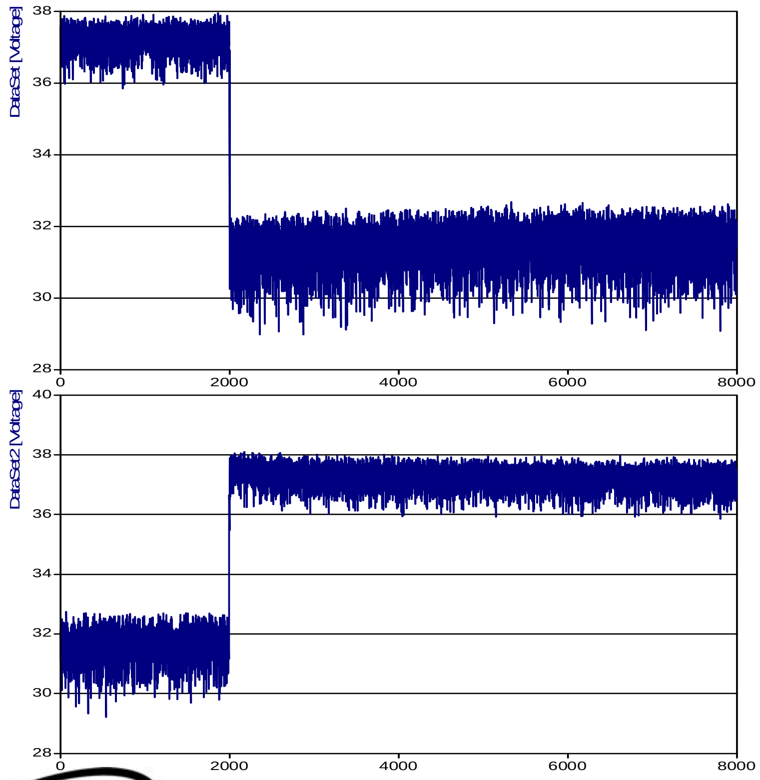
619.2c Voltage Dip and Rise for Rated Load Test

Prior test results from Army RDECOM with Mainstream's unregulated generator



28-VDC Generator		
	MIL-STD-1332B	Mainstream Unregulated Generator
Voltage – Dip	30%	24.8%
Recovery Time	2 sec	0 sec
Voltage - Rise	40%	22%
Recovery Time	2 sec	0 sec

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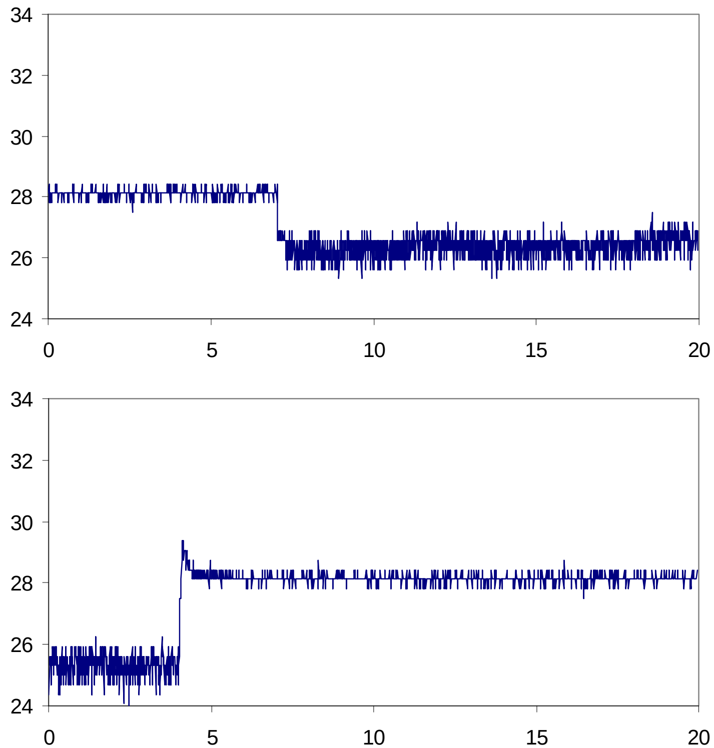
619.2c Voltage Dip and Rise for Rated Load Test

Current test results with Mainstream's regulated generator with ISA



28-VDC Generator		
	MIL-STD-1332B	Mainstream MFEG-020028
Voltage – Dip	30%	6.2%
Recovery Time	2 sec	0.1 sec
Voltage - Rise	40%	5.5%
Recovery Time	2 sec	0.6 sec

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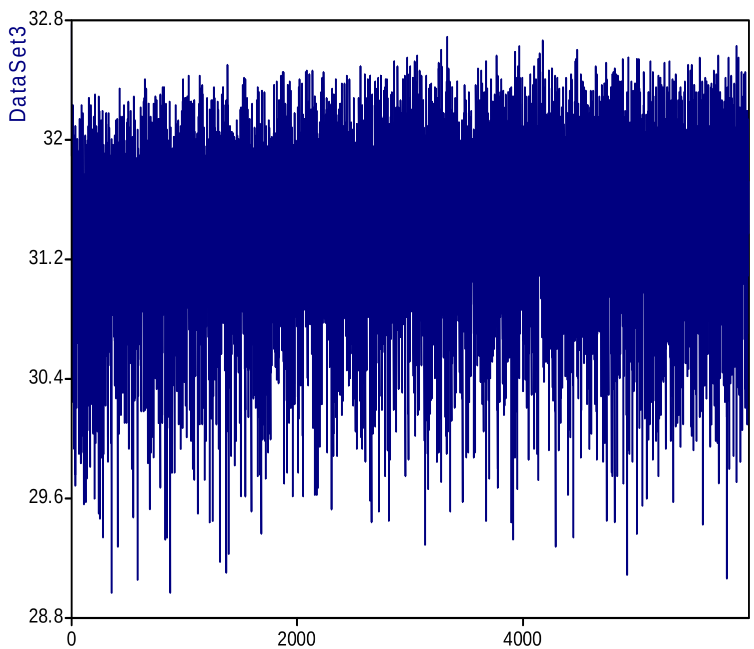
Engineering Corporation

650.1a Ripple Voltage Test

Prior test results from Army RDECOM with Mainstream's unregulated generator

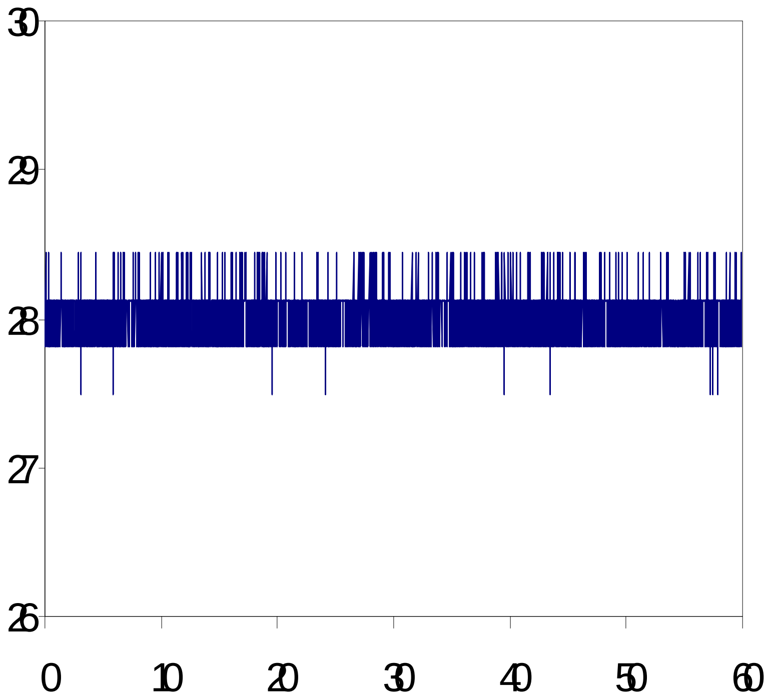


28-VDC Generator		
	MIL-STD-1332B	Mainstream Unregulated Generator
Voltage - Ripple	5.5%	9.4%*

* Reduced to 2.9% with 0.16 lb capacitor

650.1a Ripple Voltage Test

Current test results with Mainstream's regulated generator with ISA



28-VDC Generator		
	MIL-STD-1332B	Mainstream MFEG-020028
Ripple 0% Load	5.5%	0.55%
Ripple 25% Load	5.5%	0.55%
Ripple 50% Load	5.5%	0.60%
Ripple 75% Load	5.5%	0.59%
Ripple 100% Load	5.5%	0.63%

Solutions Through Advanced Technology™
MAINSTREAM
Engineering Corporation

670.1b Fuel Consumption Test

Prior test results from Army RDECOM with Mainstream’s unregulated generator

28-VDC Generator			
Load (W)	Load (%)	Fuel Consumption (lbs/hr)	Fuel Consumption (gal/hr)
0	0%	0.80	0.120
425	21%	1.04	0.156
975	49%	1.07	0.160
1460	73%	1.23	0.185
1990	100%	1.49	0.223

For Comparison: “The Power Generation Branch has numbers showing some MTGs to use only 0.26 gal/hr of JP-8 at full load. The 0.33 is a fleet maximum.” – Army CECOM

Solutions Through Advanced Technology™
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No Change Expected for the Following Tests

- 660.1d Inclined Operation Test
  - 20°
- 661.2c Sound Level Test
  - 79 dBA at 7 m
- 690.1d Endurance Test
  - RDECOM testing for 150 hrs
- 710.1d High Temperature Test
  - RDECOM will test to 135°F (previously 125°F)

Changes Expected for the Following Tests

- 640.1d Maximum Power Test
  - More efficient power converter will increase max power
- 701.1d Starting and Operating Test (Extreme Cold Battery Start)
  - ISA with electric start will allow for extreme cold weather starting

Summary

- Mainstream's 2-kW Generators
  - 28 VDC
  - 120 VAC, 60 Hz
- 39% smaller than MTG
- 17-25% lighter than MTG
- 33% more efficient than MTG
- 3-6x more reliable than MTG
- New Features:
  - ISA
  - Battery charging circuit
  - Auto-start/stop
  - Hybrid-electric ready
  - AC inverter with soft-start

Contact Information

- Company Address

  Mainstream Engineering Corporation

  200 Yellow Place

  Rockledge, FL 32955

  (321) 631-3550

  www.mainstream-engr.com

- Points of Contact
  - Technical: Greg Cole, gsc@mainstream-engr.com
  - Contracts: Michael Rizzo, mar@mainstream-engr.com
- Booth #312

Workshop

Battery Technical Manuals and Milspecs

Susan M. Waggoner
Electronics Engineer
Code 6095, Bldg. 3287W
300 Highway 361
Crane, IN 47522-5001
Phone 812-854-4103, DSN 482-4103
Fax 812-854-1212
susan.waggoner@navy.mil

- **Update**
- **Comments**
- **Q&A**

- **Technical Manuals**
- **Milspecs**
- **Batteries**
- **Battery chargers**

Case Study –

Reducing Premature Failure of Parts with Interactive Virtual Training for Generator Operators

Joint Service Power Expo
San Diego
April 24-27, 2007

Erik Kaas
Director, Product Management
NGRAIN Corporation
ekaas@ngrain.com

Agenda

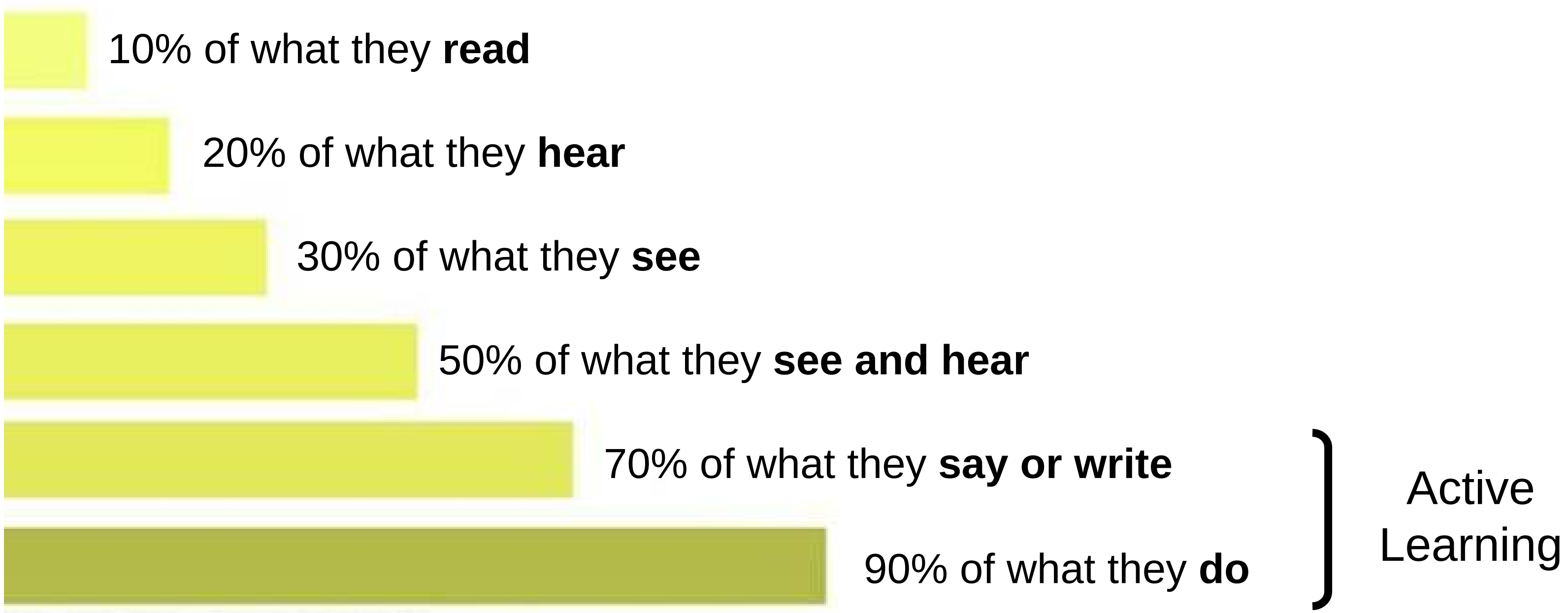
- Training Challenges
- Virtual Maintenance Trainers
- Case Study – 3kW Tactical Quiet Generator
- Conclusions

Common Challenges in Training

- Some tasks cannot be trained, due to **expense** or **lack of access to equipment**
- Soldiers receive limited training before being deployed: task-based, **on-the-job training** is critical
- Training **budgets are limited**, yet training demand is increasing
- Total Package Fielding requires rapid and effective **New Equipment Training**

Learning Theory

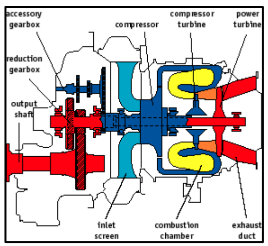
Students Remember



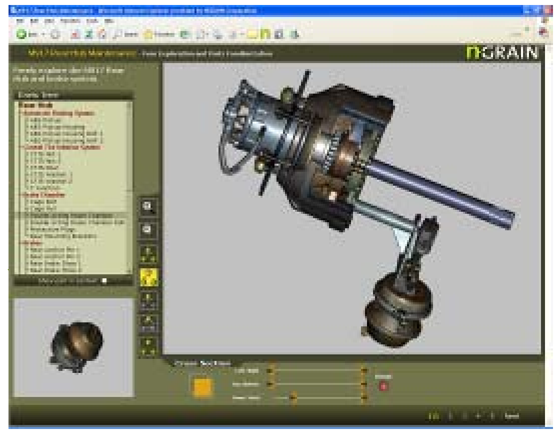
Source: Airbus/Journal of Civil Aviation Training (Issue 1, 2006)

Training Methods

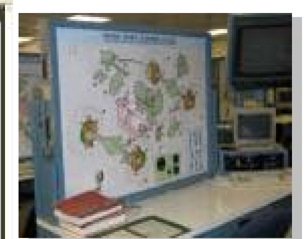
Text



Multimedia



Interactive Virtual Maintenance Trainers



Hard Trainers

Live Equipment

- ✓Low cost
- ✓Easy to create and update
- ✓Anytime, anywhere access
- ×Low learning effectiveness

- ✓Low cost
- ✓Easy to create and update
- ✓Anytime, anywhere access
- ✓High learning effectiveness

- ×High cost
- ×Difficult to create and update
- ×Limited access
- ✓High learning effectiveness

nGRAIN®

Virtual Maintenance Trainers

Virtual 3D equipment simulations to:

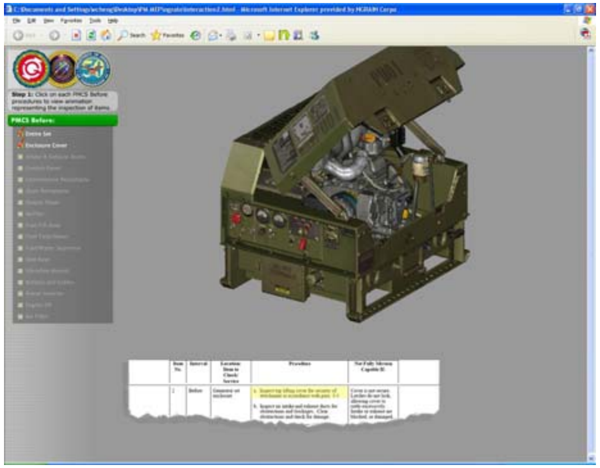
- *Familiarize*
- *Acquire*
- *Practice*
- *Validate & Test*

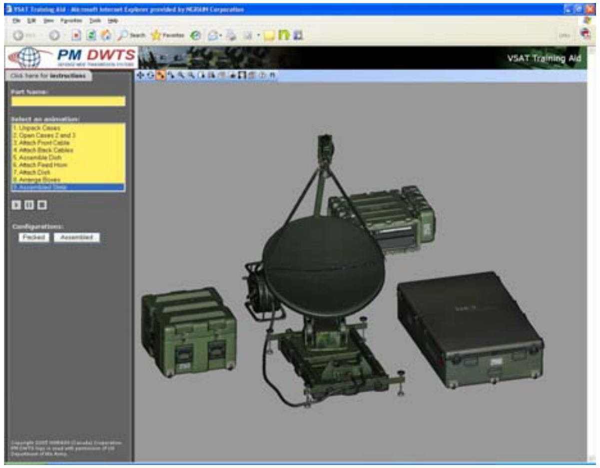
Proven ROI: Train 60% Faster

nGRAIN®

Benefits of Virtual Maintenance Trainers

- ✓ Let students learn from their mistakes, **safely**
- ✓ Let training take place **without the expense** of equipment
- ✓ **Reduce wear and tear** on equipment
- ✓ Enable **task-based, on-the-job training**
- ✓ Students are more engaged and **motivated**



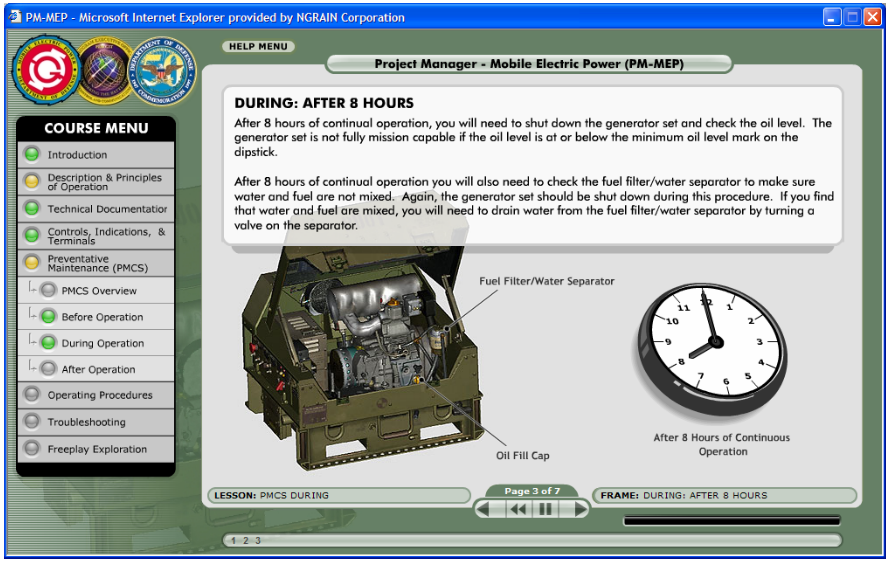


Case Study: 3kW TQG Operator Course

Challenge: Premature failure of generator parts due to operator error

Objective: Provide more effective refresher and sustainment training

Results: Reduced premature failure of parts



Case Study - Implementation

Based on Technical Manual

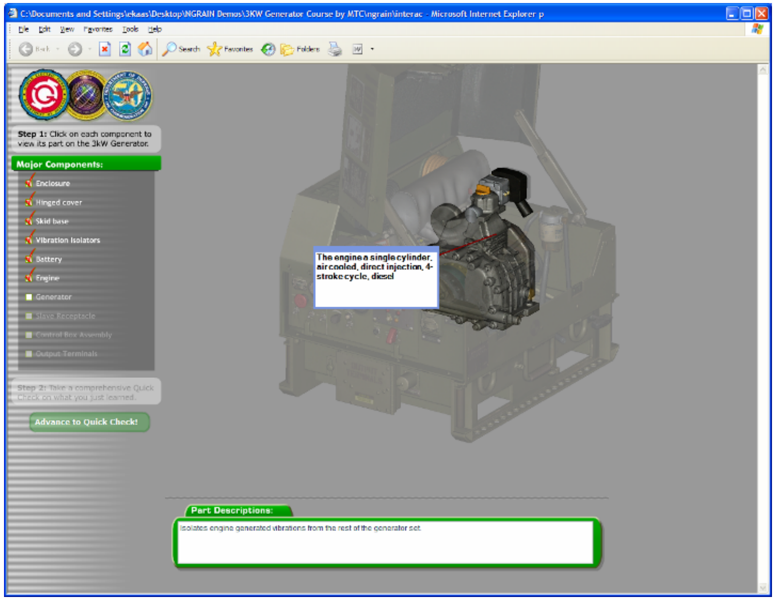
- Cross reference
- Follow the procedure

Visual & Interactive

- Engage students
- More intuitive explanations
- Validate & test

Computer Based

- Used by instructor
- Used by students
- Used by deployed soldiers to refresh or just in time training



Case Study - Demonstration

Course Layout

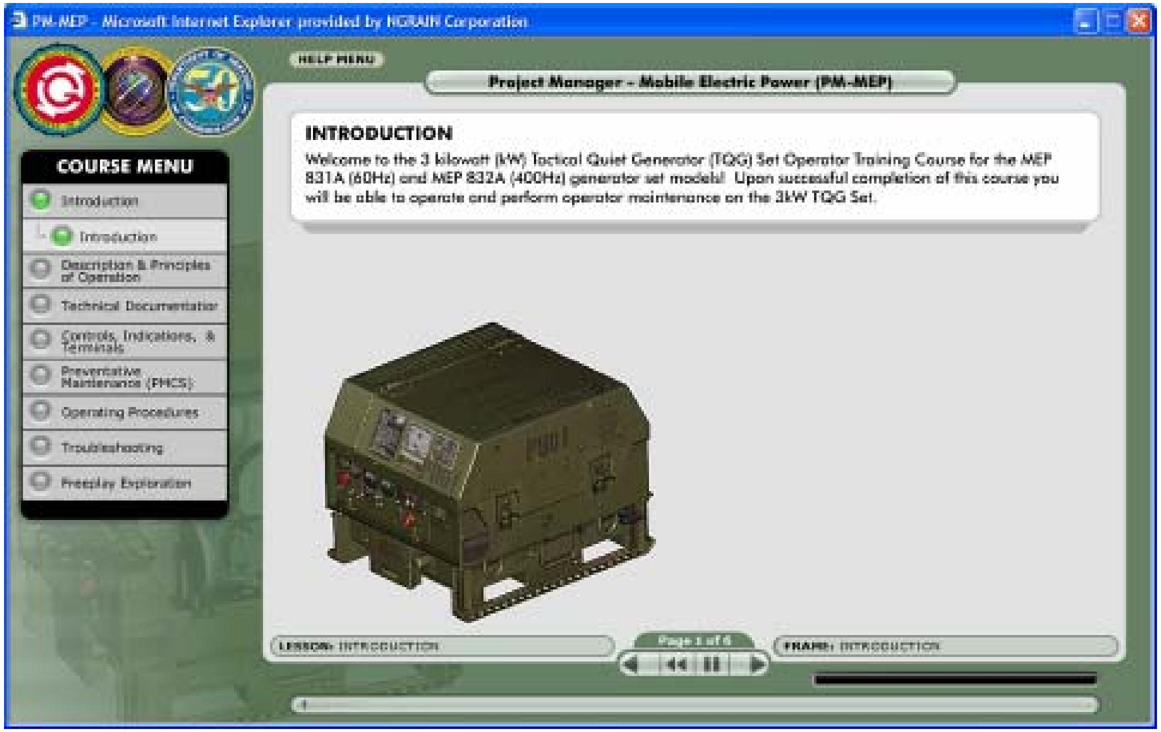
Component Familiarization

Controls

PMCS

Operating

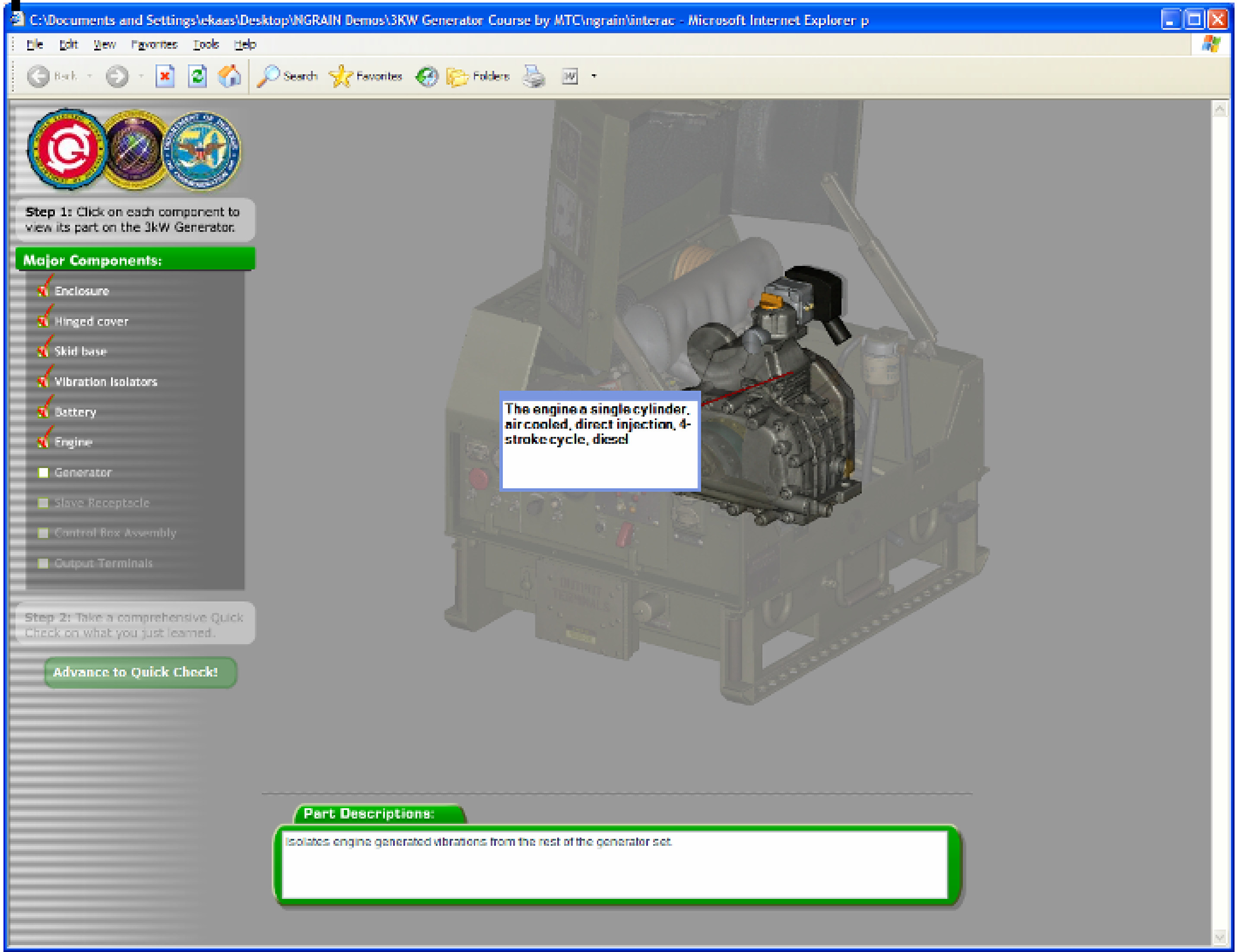
Troubleshooting



nGRAIN®

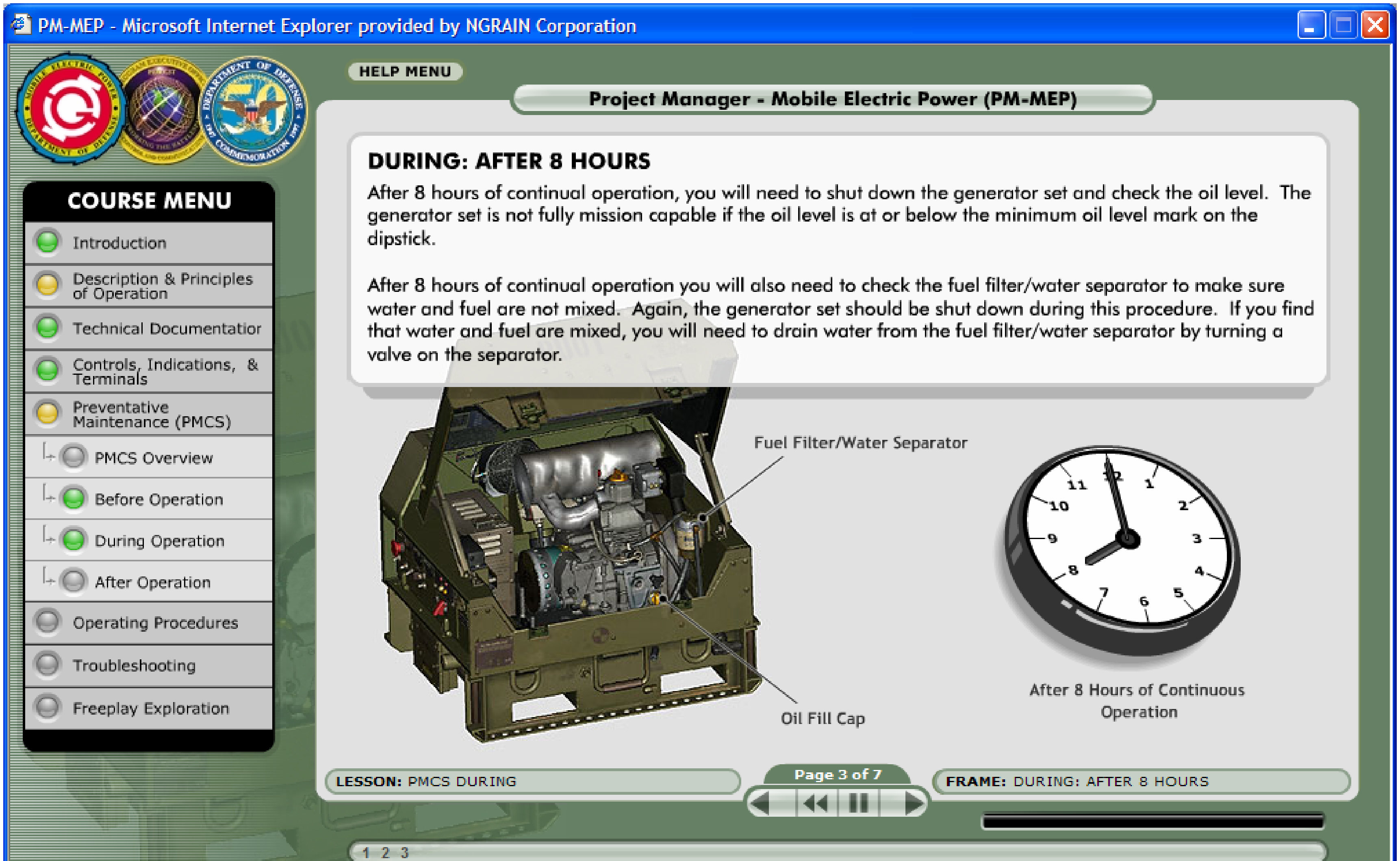
Course Layout

Component Familiarization

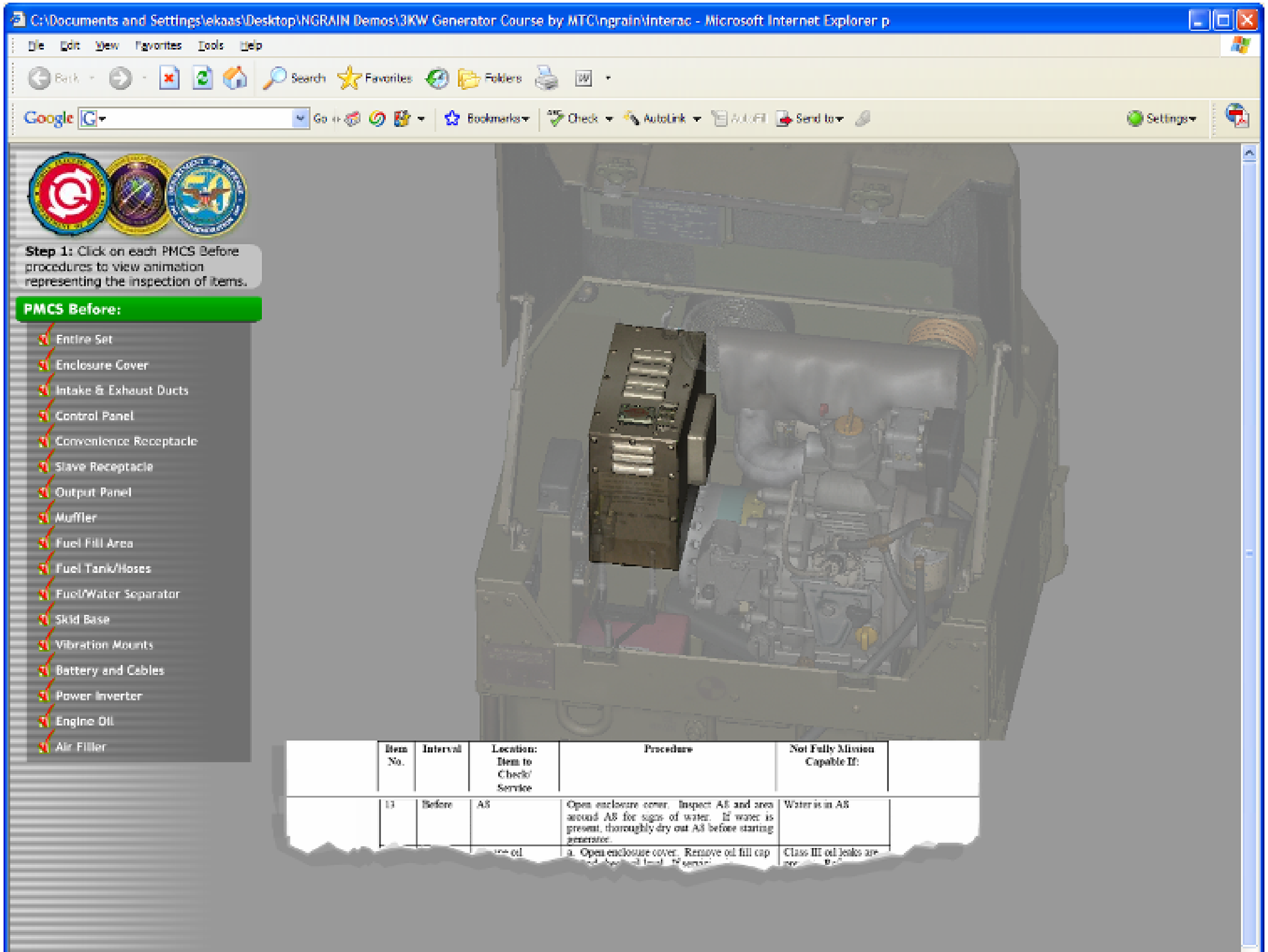


Controls, Indicators & Terminals

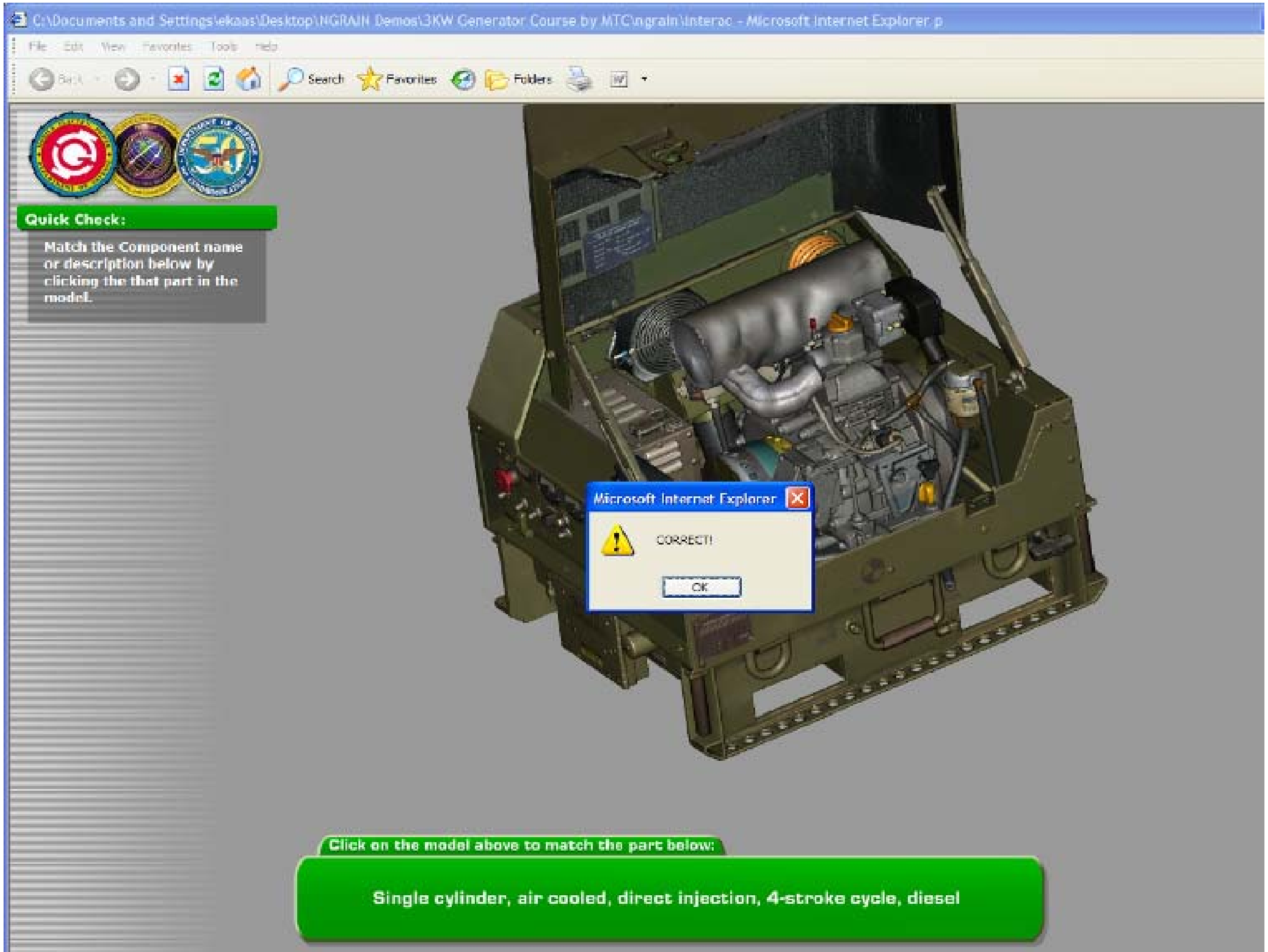
PMCS


PM-MEP - Microsoft Internet Explorer provided by NGRAIN Corporation
HELP MENU
Project Manager - Mobile Electric Power (PM-MEP)
COURSE MENU
Introduction
Description & Principles of Operation
Technical Documentatior
Controls, Indications, & Terminals
Preventative Maintenance (PMCS)
PMCS Overview
Before Operation
During Operation
After Operation
Operating Procedures
Troubleshooting
Freeplay Exploration
DURING: AFTER 8 HOURS
After 8 hours of continual operation, you will need to shut down the generator set and check the oil level. The generator set is not fully mission capable if the oil level is at or below the minimum oil level mark on the dipstick.
After 8 hours of continual operation you will also need to check the fuel filter/water separator to make sure water and fuel are not mixed. Again, the generator set should be shut down during this procedure. If you find that water and fuel are mixed, you will need to drain water from the fuel filter/water separator by turning a valve on the separator.
Fuel Filter/Water Separator
Oil Fill Cap
After 8 Hours of Continuous Operation
LESSON: PMCS DURING
Page 3 of 7
FRAME: DURING: AFTER 8 HOURS
1 2 3

PMCS Procedure Illustration



PMCS Practice



Operating & Troubleshooting

Conclusions

Interactive virtual maintenance trainers offer numerous benefits:

- Lets training take place even if there is no equipment available
- More effective for task-based learning objectives
- Operationally deployable
- Very suitable to address TQG training challenges

Thank you! Questions?

For more information:

Erik Kaas
604-669-9973 ext 267
ekaas@ngrain.com

Case studies and Whitepapers:
www.ngrain.com

To order 3kW TQG Operator Course Computer-Based Training CD:
www.pm-mep.army.mil/logistics/TrgMat.htm

Electric Drive Approach to Mobile Power Platforms

Oshkosh Truck Corporation

Nader Nasr
Chief Engineer
Advanced Products Group

GET THERE FIRST

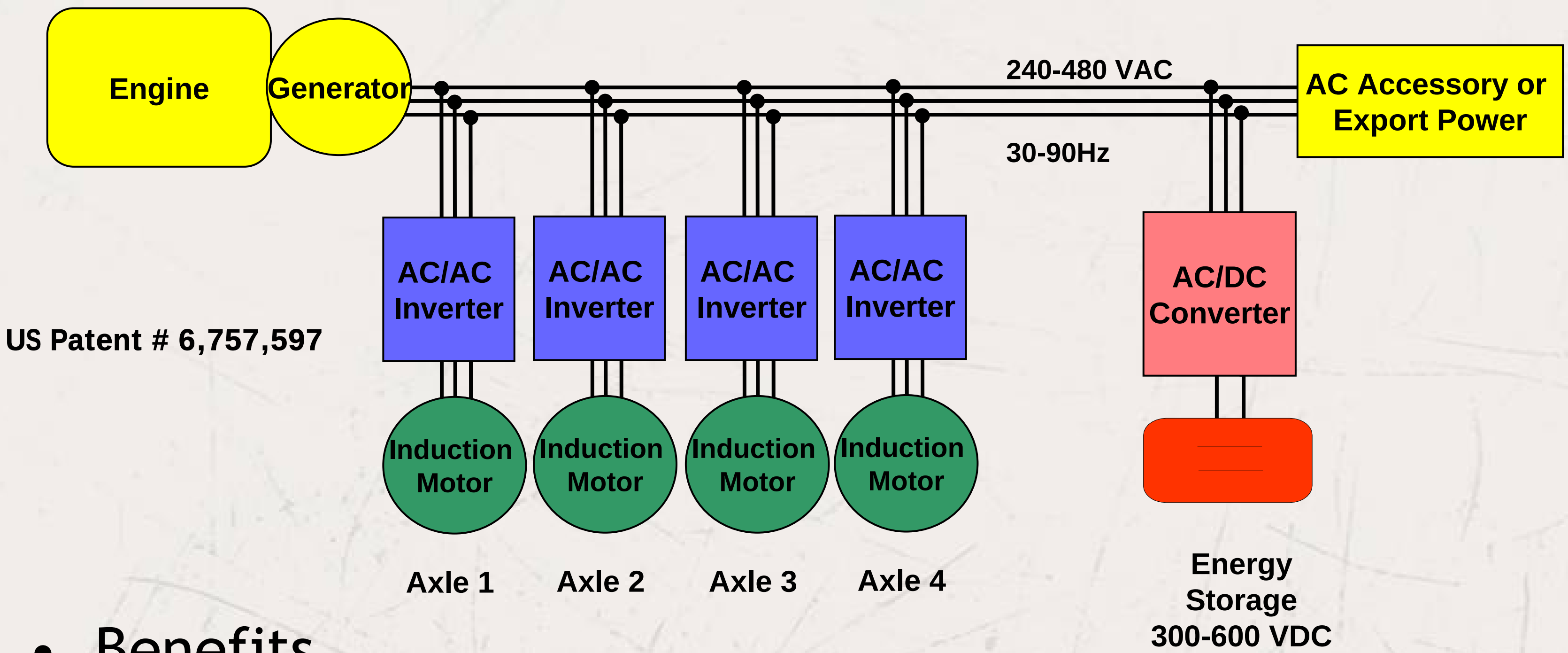
On Board Vehicle Power

Responding to military's needs for power in the theater

- Military Relevance
  - Increased mobility, power for onboard weapons
  - Back up power for mission critical equipment
  - Increased cargo space, reduced logistic footprint
  - Power options for early entry forces, high speed mobility

GET THERE FIRST

ProPulse® Electric Drive System



- Benefits
  - Large amounts of AC power available for export
  - Energy storage is an option
  - No batteries
  - Zero voltage maintenance
  - Improved fuel economy
  - Enhanced packaging flexibility

GET THERE FIRST

HEMTT A3

- TACOM PM Heavy
- Improved fuel efficiency
- 100 kW Export power

MTVR OBVP

- ONR funded program
- 120 kW of export power
- Maintain vehicle performance

ProPulse® Implementation

Advanced Heavy Hybrid Propulsion System

- DOE / NREL 3 yr program
- Target 2x fuel economy
- Validation vehicle / Waste Management

Homeland Security

ARFF Applications

OSHKOSH

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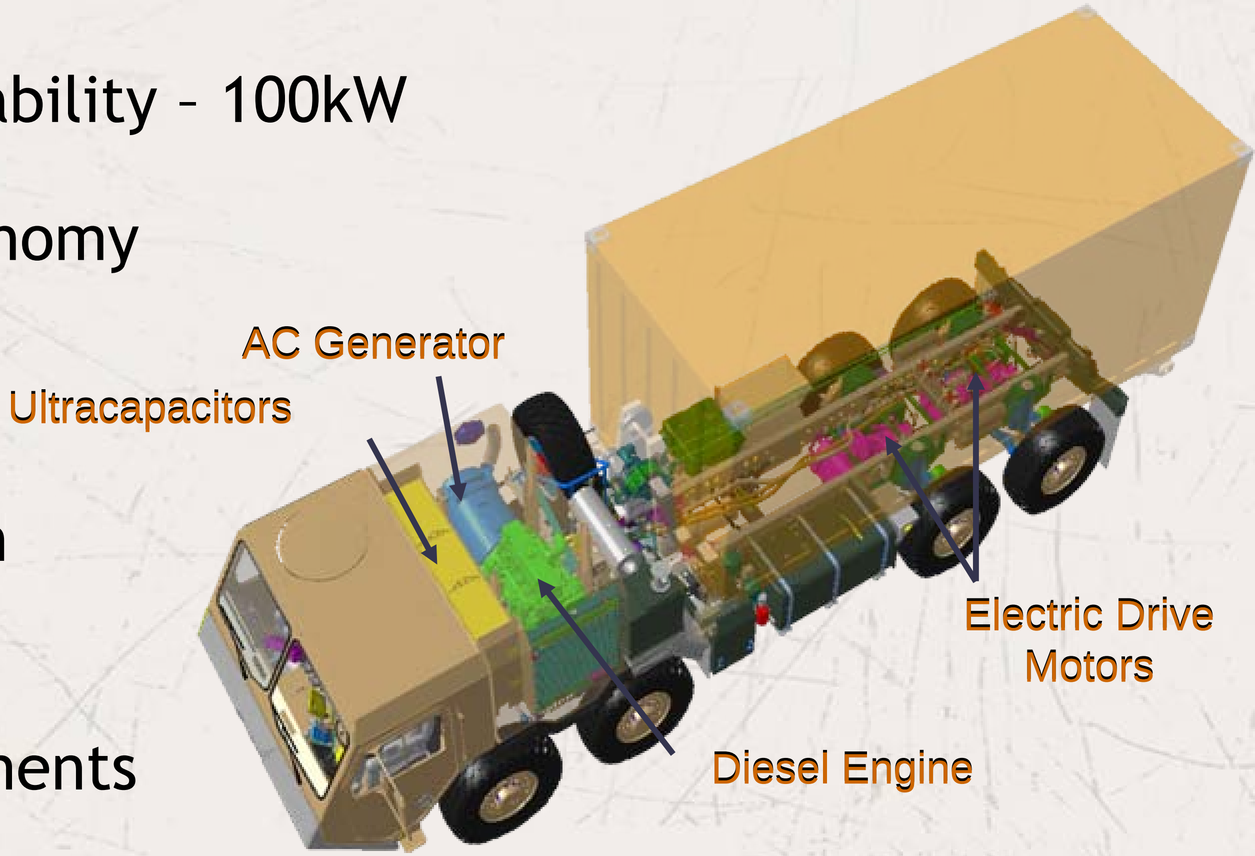
HEMTT A3

HEMTT A3

Program Primary Objectives

- Export Power Capability – 100kW
- Improved fuel economy
- Advanced Load Handling System light weight design
- Meet HEMTT objective requirements



GET THERE FIRST

HEMTT A3
Key Technologies – Present

- Light weight modular design
- Diesel electric series hybrid
- Ultracapacitor Energy Storage
  - No batteries, life of vehicle design
- 100kW Exportable AC power
- Variable height independent suspension
- Multiplexed electrical system w/ advanced diagnostics
- C-130 unload capability
  - Enhanced Load Handling System (ELHS)

HEMTT A3

Testing Completed

- 12K miles off road – Nevada
- Vehicle Performance testing
  – PSD Aberdeen
- Export Power Performance
  – PSD Aberdeen
- Fuel Economy >20% improvement

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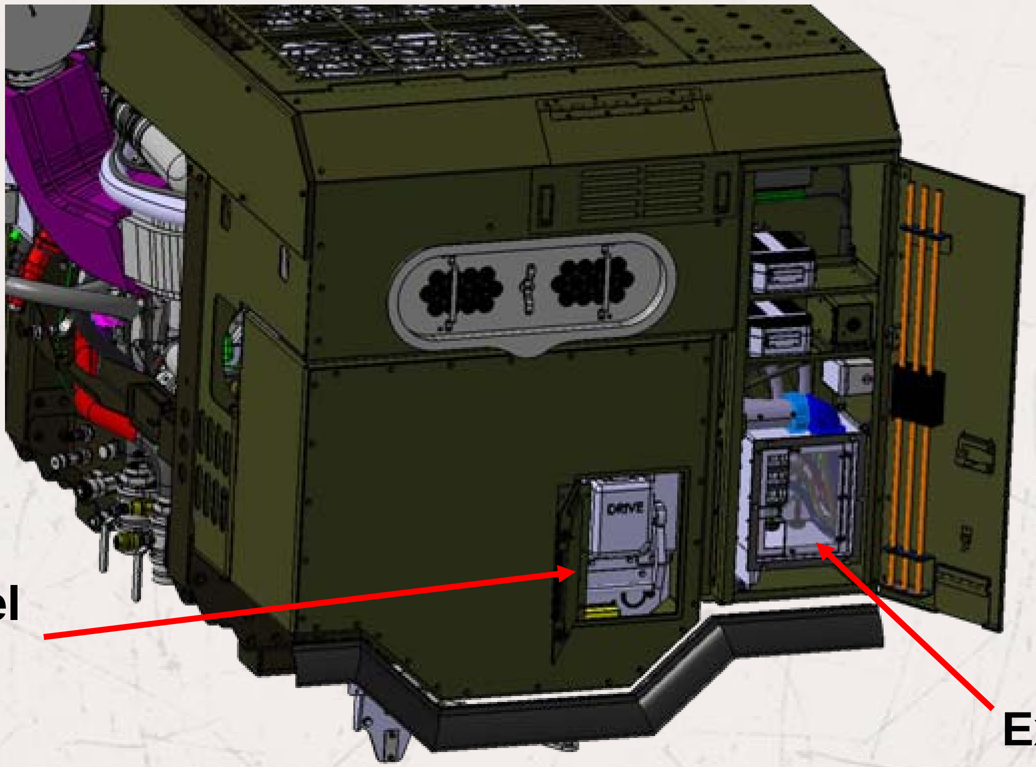
HEMTT A3 – Power Module



Reconnect Panel

Export Power Interface

Exportable Power:

100 kW @ 480 V or 240 V 60 Hz

86 kW @ 416 V or 208 V 50 Hz

86 kW @ 120 V 50 Hz or 60 Hz

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Export Power Vehicle Interface Screens

Export Power Controlled From Inside Cab

- Adjustable voltage (primary voltage and fine adjustment)
- Adjustable frequency (primary frequency and fine adjustment)
- AC contactor on/off (turning on and off output power)

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Export Power

Platform System Demo, August 2006 Aberdeen Test Center

Tests Performed:

- Short Term Transient
  - Response MIL-STD-705C
  - Section 608.1
- Long Term Steady State
  - Stability MIL-STD-705C
  - Section 608.2
- Harmonic Analysis
  - MIL-STD-705C
  - Section 601.4

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MTVR On-Board Vehicle Power
Office of Naval Research

BAA – 04 – 011

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MTVR

- Performance
  - Oshkosh TK-4™ Independent Suspension
  - 70% Offroad Mission Profile
  - 7.1 ton payload cross country
  - 15 ton payload primary and secondary roads
- MTVR Based Variants
  - Cargo, Dump Truck, Wrecker, HIMARS Re-Supply Vehicle, Tractor, LHS (load handling system)

MTVR OBVP Program – ONR Objectives

- Provide vehicle integrated power source
  - 120 kW of military grade export power
  - 21 kW of power on the move
- Easy retrofit of existing MTVR vehicle
- Use host vehicle's diesel engine for both mobility and power generation
- Retain MTVR performance
- Minimize weight
  - 25 lb / kW Threshold
  - 20 lb / kW Objective

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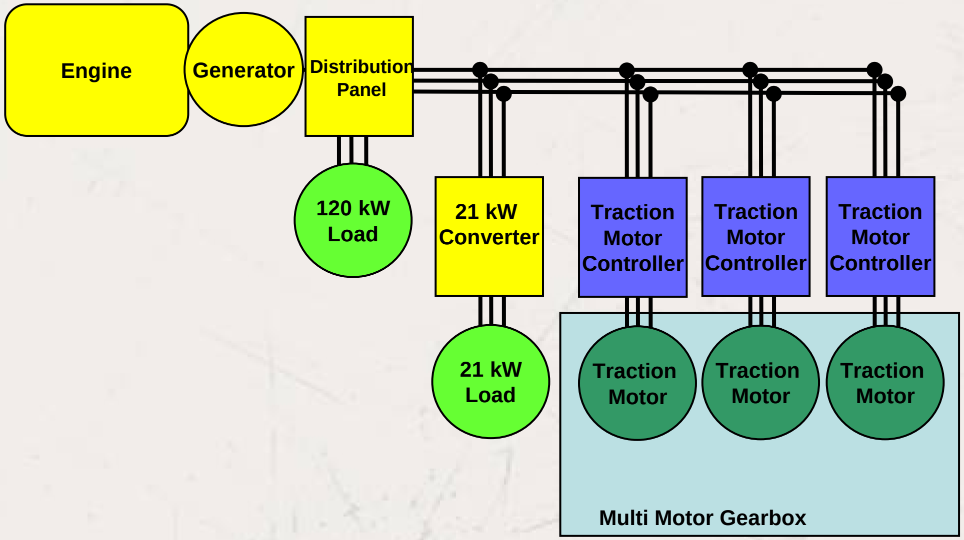
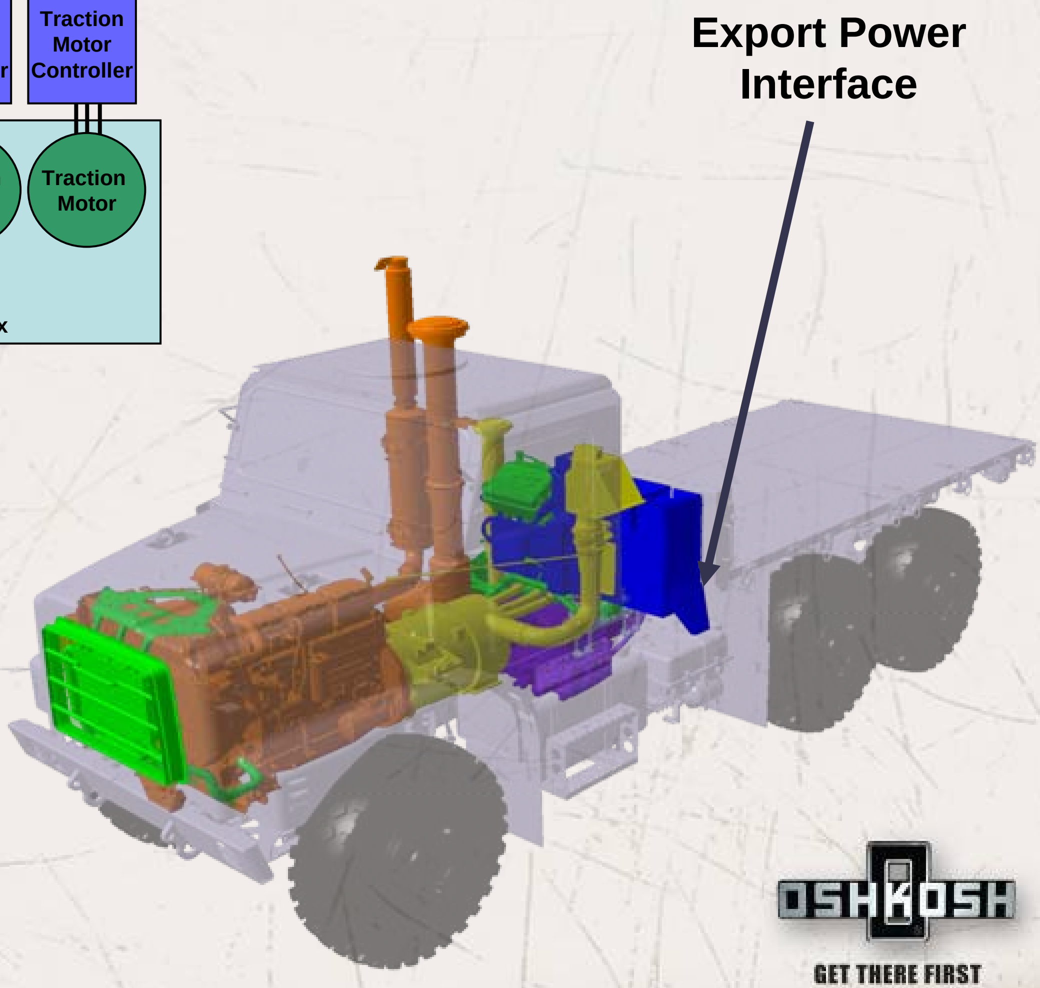
OBVP System Overview





- Pure diesel electric solution
- No Energy Storage
- Synchronous generator design

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OBVP Design

- 300 kW traction generator used for vehicle driving and providing stationary export power
- Synchronous generator design
  - Clean military grade power
  - No need for power electronics or conditioning
- Cab display is used to initiate switch over, voltage and frequency adjustments and diagnostics

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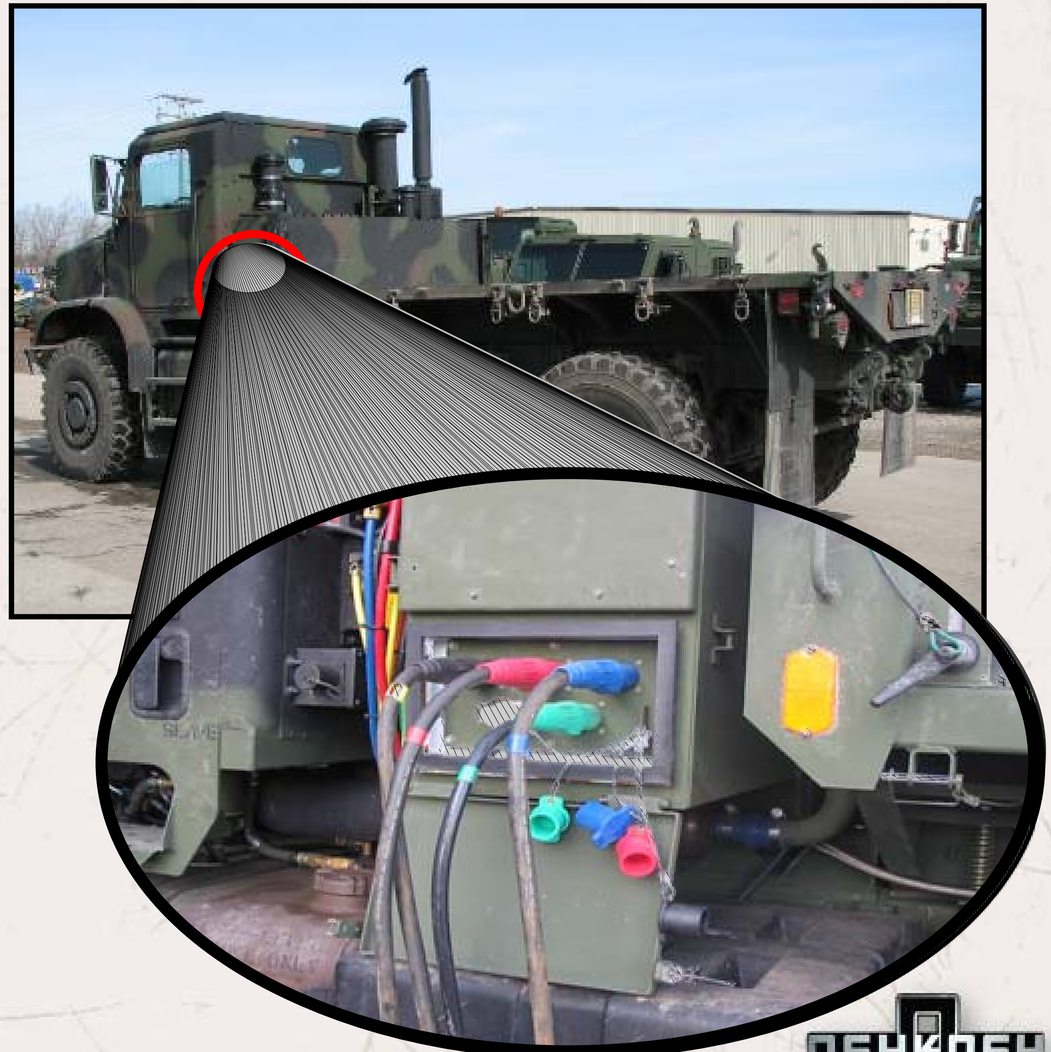
Export Power Performance

- 5 wire CAM style connection – Marine Corps request
- Meets requirements of tactical quiet generator
  - 120 kW of stationary export power
  - 21 kW of power on the move
- Exceeds objective requirements, achieved 19 lb/kW



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Project Status

- OBVP build complete – January 2007
- Vehicle commissioning complete – March 2007
  - Basic driving functionality
  - 120kW stationary export power
- Deliver for Government durability testing – December 2007

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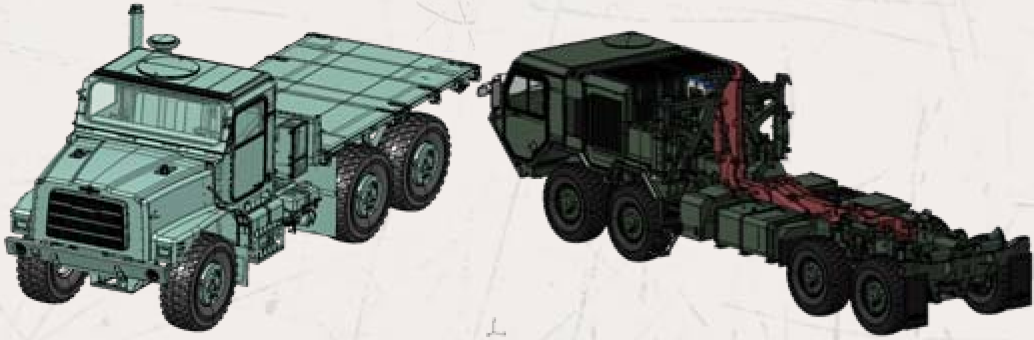
Summary

- Oshkosh's diesel electric technology presents a unique and superior solution for large mobile power requirements
  - lb/kW
  - $/kW
  - Power quality
  - No batteries



- Leverage developed ProPulse® system and components
- Provide simple wiring interface, and swift transition to exporting power

OSHKOSH
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Far Reaching Benefits

- Commercial
  - Improved MPG
  - Lower emissions
  - Packaging flexibility
  - Disaster relief
    - Export power 100 kW+
- Defense
  - Lower logistics burden
  - Export power
    - 100 kW+ Mil spec AC power
  - Higher performance
  - Increased functionality
  - Improved MPG

ProPulse® Technology Demonstrator – Katrina Support

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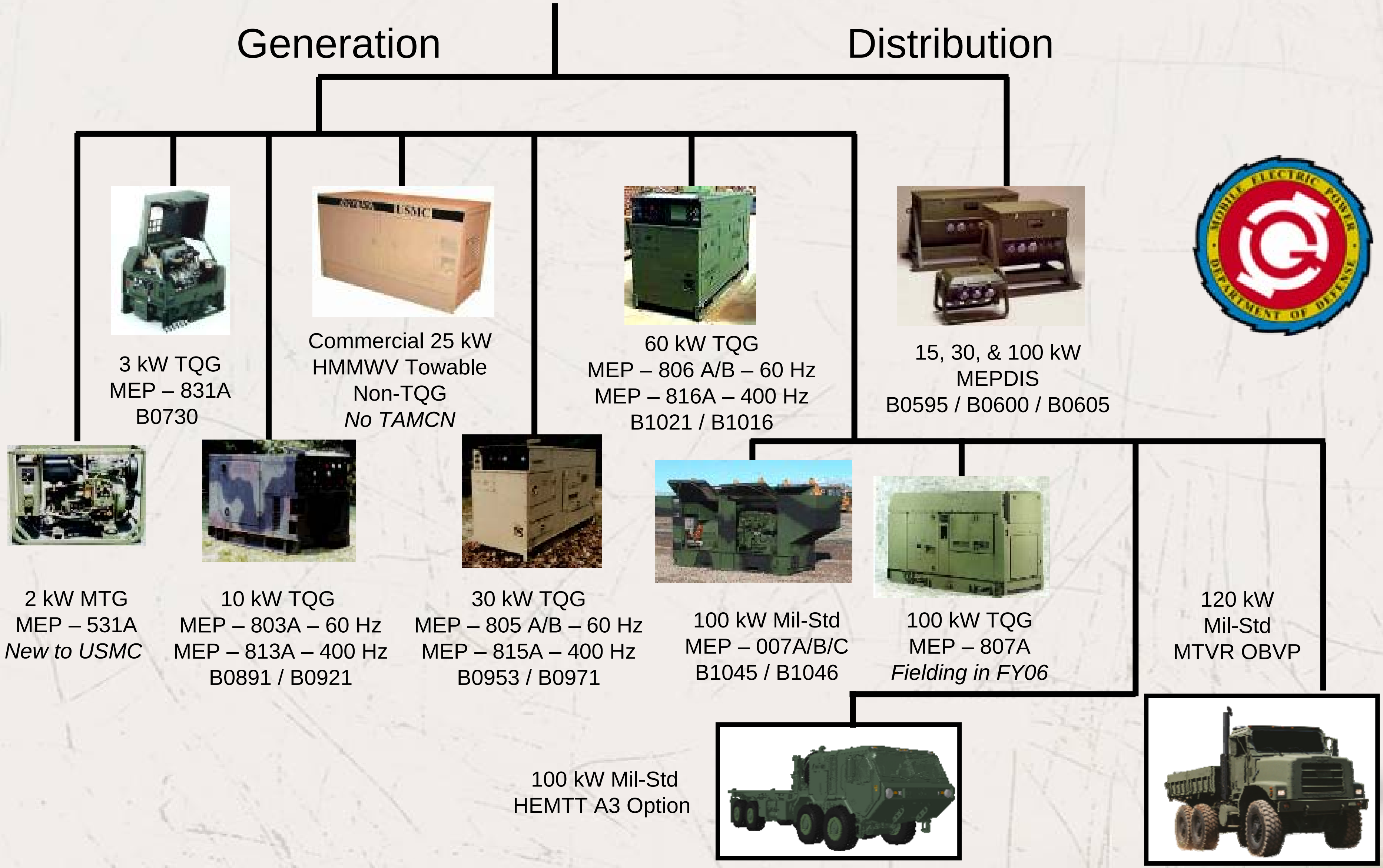
MEP Power Generation



Your Questions

OSHKOSH

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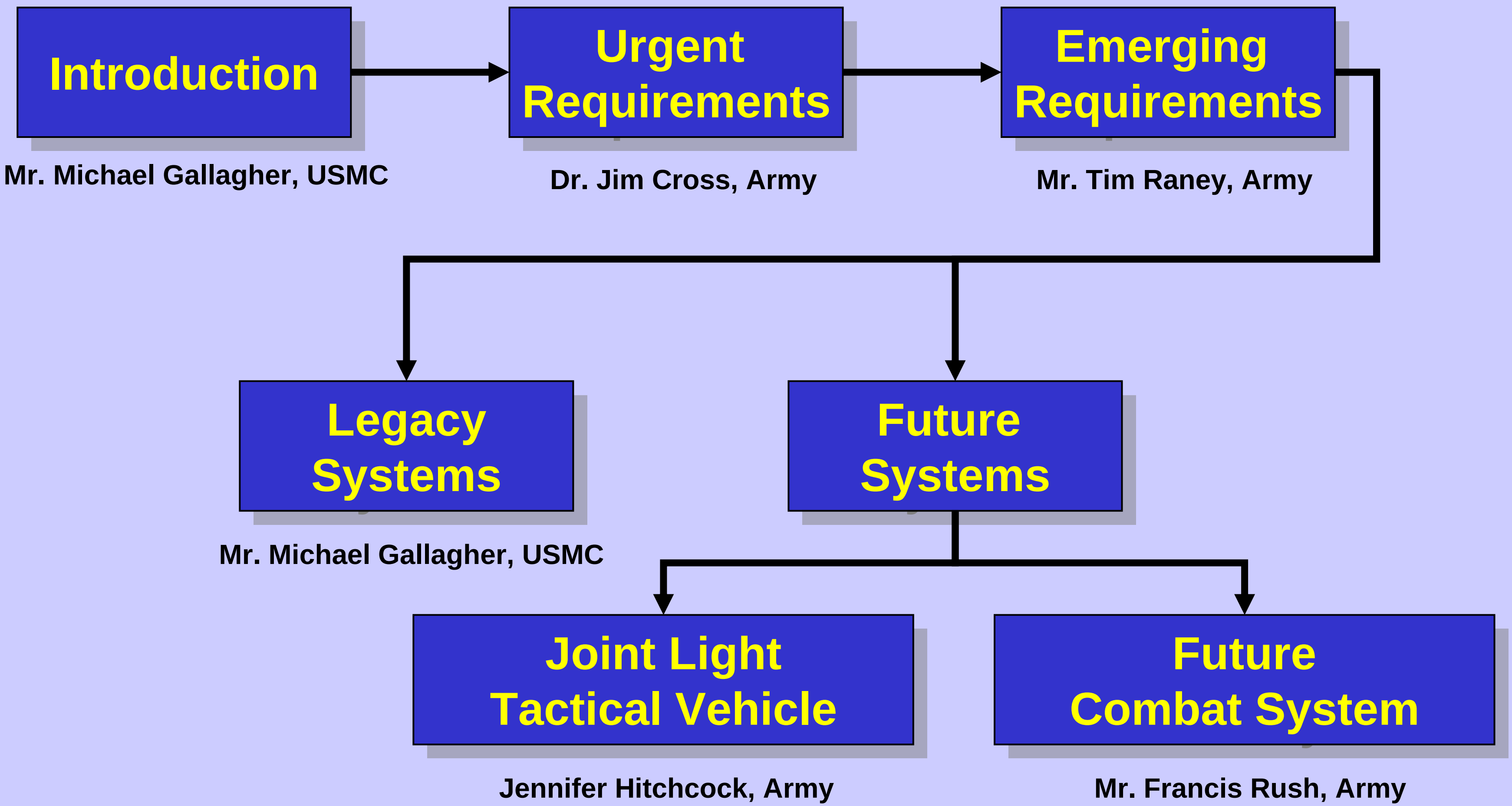
On-Board Vehicle Power

Joint Service Power Exposition
25 April 2007

Session 12

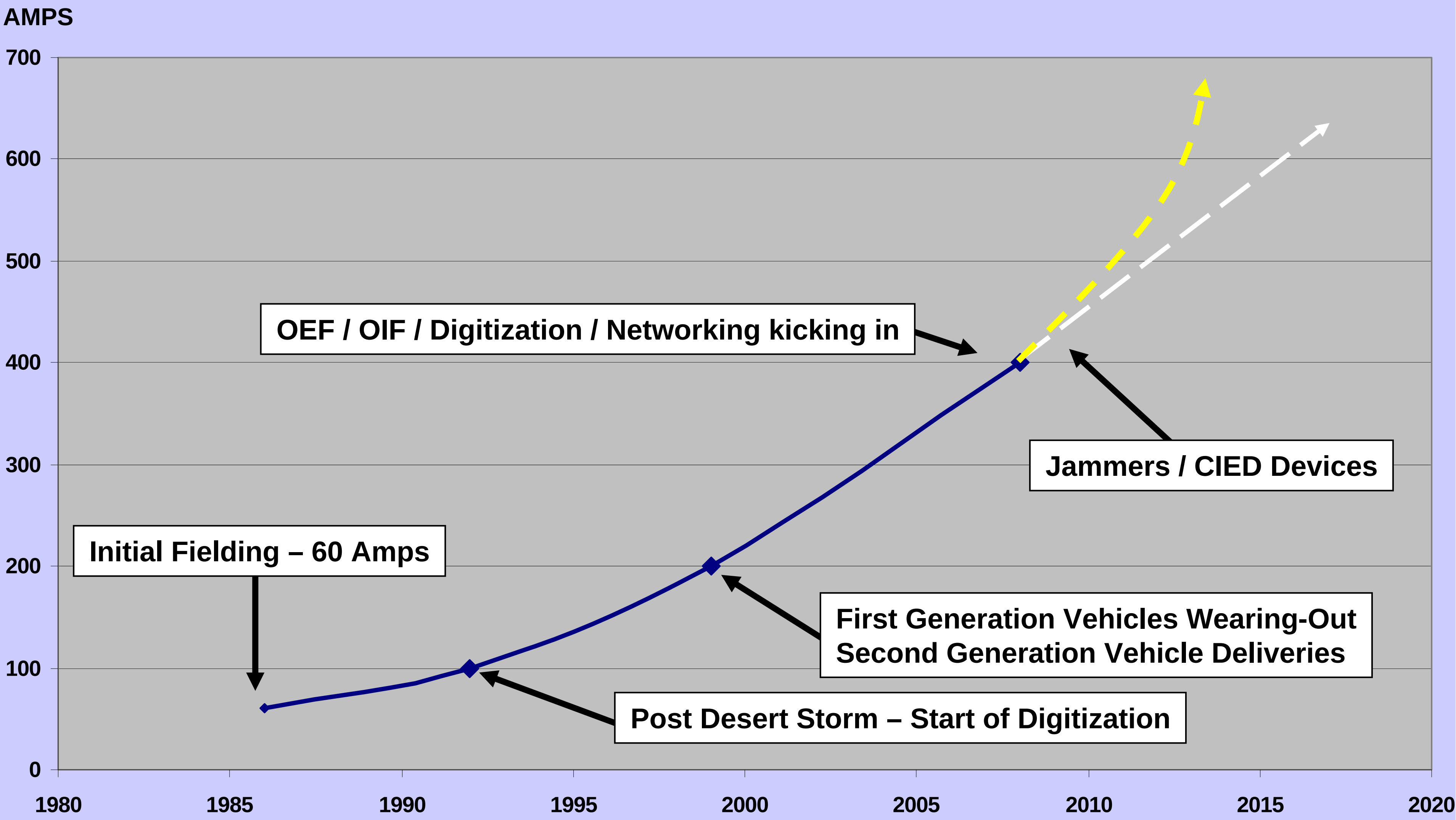

Introduction
Mr. Michael Gallagher, USMC
Urgent Requirements
Dr. Jim Cross, Army
Emerging Requirements
Mr. Tim Raney, Army
Legacy Systems
Mr. Michael Gallagher, USMC
Future Systems
Joint Light Tactical Vehicle
Jennifer Hitchcock, Army
Future Combat System
Mr. Francis Rush, Army

Session 14

In <u>no</u> order of preference

• William Henrickson	E-power
• Nadr Nasr	Oshkosh Truck Co
• Stephen Cortese	BAE Systems
• Tom Trzaska	General Dynamics

Alternator Amperage Rating on HMMWV at 28 VDC



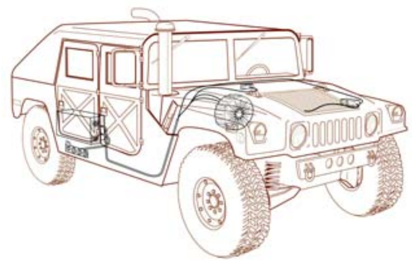
Marine Corps
On-Board Vehicle Power Systems for Legacy Military Vehicles

Joint Service Power Exposition
2007

On-Board Vehicle Power Systems

DC-AC Power Inverters
1500- 3000 watts

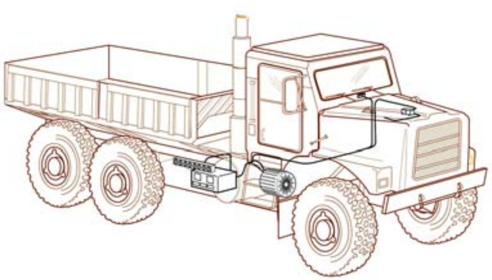
OBVP - Medium
30 kW Add-on HMMWV



Retrofits for
In-Theater Assets

OBVP - Small
5 – 8 kW (HMMWV)

OBVP - Large
120 kW (MTVR)



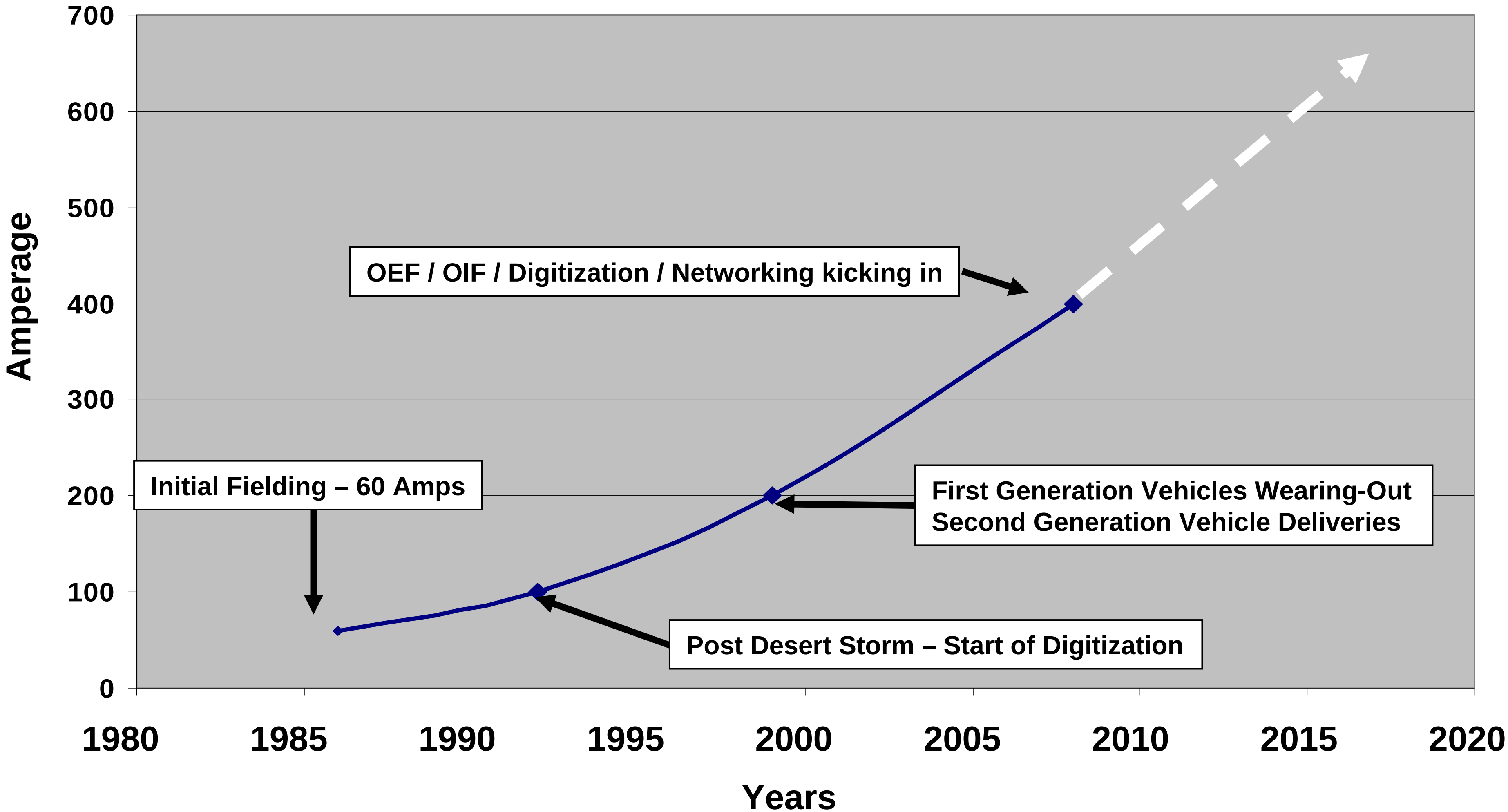
Vehicle Power Inverters

- **Requirement for DC-AC Power Inverter**
  - **18-32 VDC input**
  - **120 VAC, single phase output**
  - **1800 watts minimum output**
  - **Easily installed**
  - **Readily available / commercial based item**
- **Market Research and testing conducted**
- **GSA schedule showed adequate competition**
- **Solicited, competed, awarded in 2007**
- **Multi-year contract awarded to IRIS QP-1800**
  - **Inverter**
  - **Ruggedized carrying case**
  - **NATO cable connector**
  - **5600 articles planned**

On-Board Vehicle Power - Small

- **Up to 400 Amps at 28 VDC needed**
- **Army has lead on retrofit kit**
  - **Vehicles in theater**
  - **DC power needs**
- **USMC will procure kits in 2007/2008**
  - **M1114, M1151, M1152 configurations**
- **Continuing to investigate / test inverters at higher power levels for AC power needs**
- **Future USMC vehicles will be procured with 400 Amp capacity (LVSR, MRAP)**

Alternator Amperage Rating on HMMWV at 28 VDC

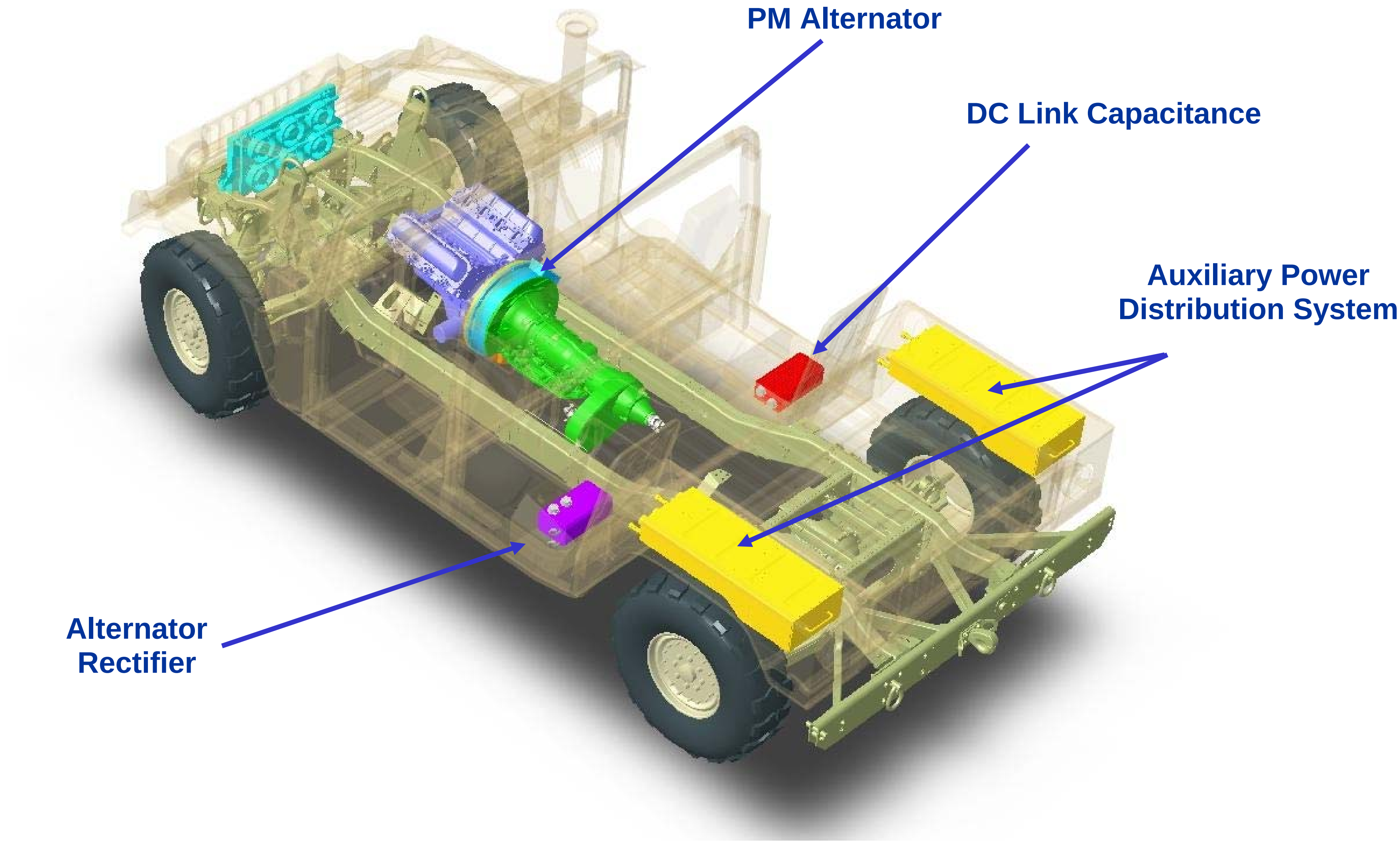


On-Board Vehicle Power
Medium & Large Systems

- Technology Demonstrations funded by Office of Naval Research
- HMMWV based system:
  - 30 kilowatts stationary / 10 kilowatts on-the-move
  - Will be mounted on HMMWV M1123
  - Power output at 120/208 VAC, 60 hz
  - Two vehicles can be connected in parallel (60 kW output)
  - Can synchronize to MEP-805B generator
- MTVR based system:
  - 120 kilowatts stationary / 20 kilowatts on-the-move / 3 kW transition
  - Mk 23 Truck
  - Power output at 120/208 VAC, 60 hz
  - Can synchronize to MEP-807A generator
- Vehicles will be delivered in 2007 for evaluation

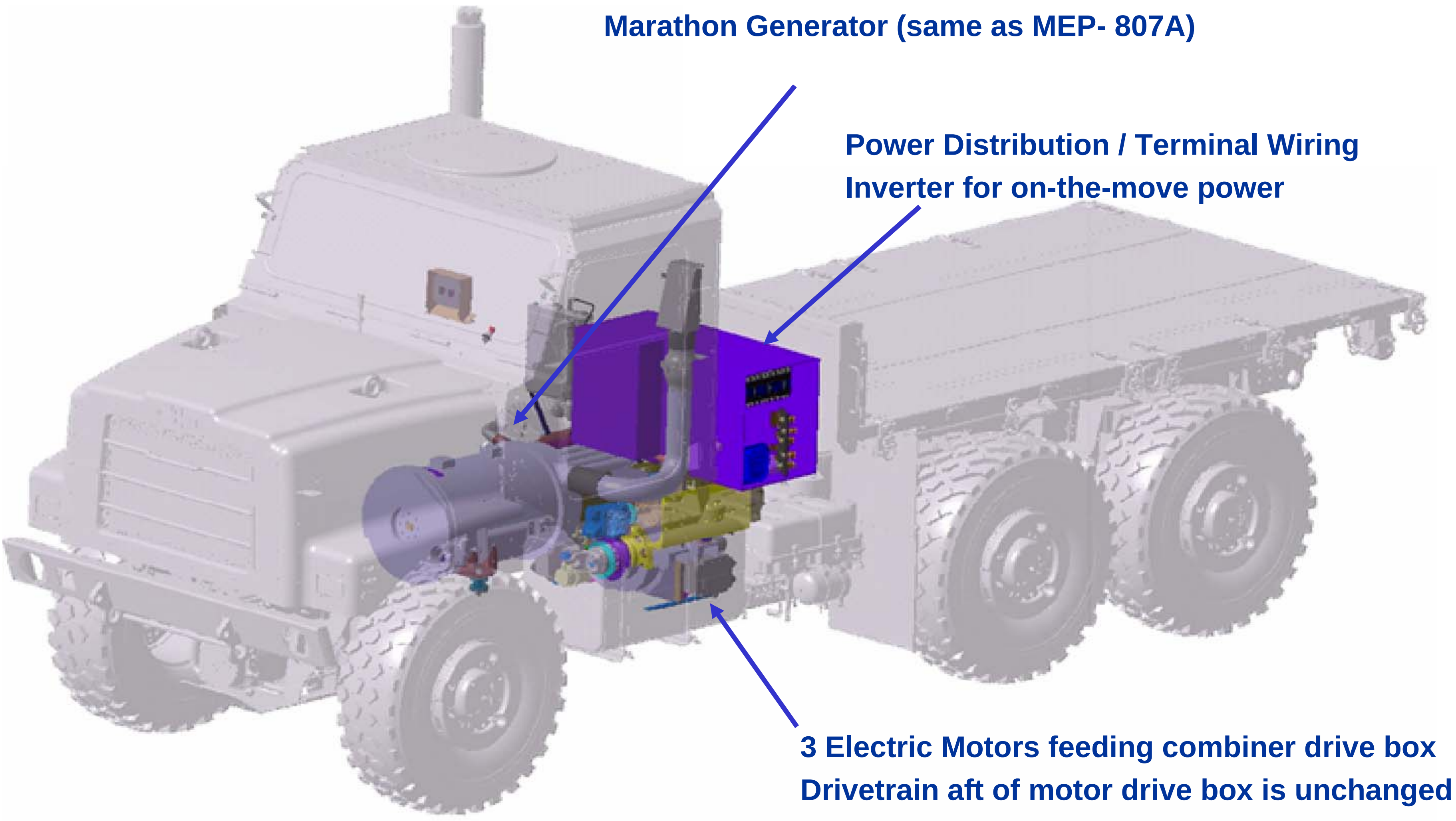
On-Board Vehicle Power - Medium

DRS Technologies Selected for Hardware Fabrication Phase

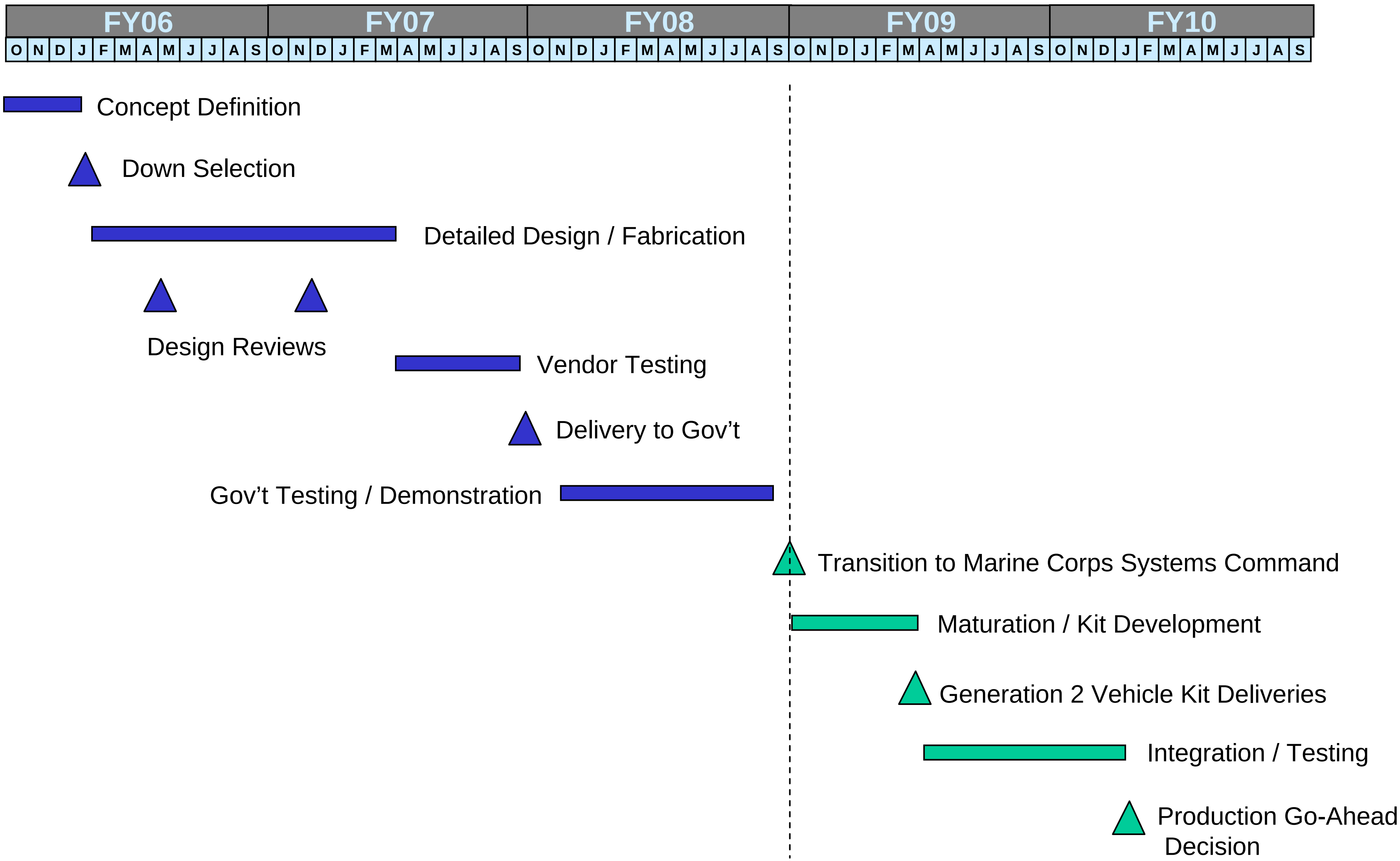


On-Board Vehicle Power - Large

OshKosh Selected for Hardware Fabrication Phase



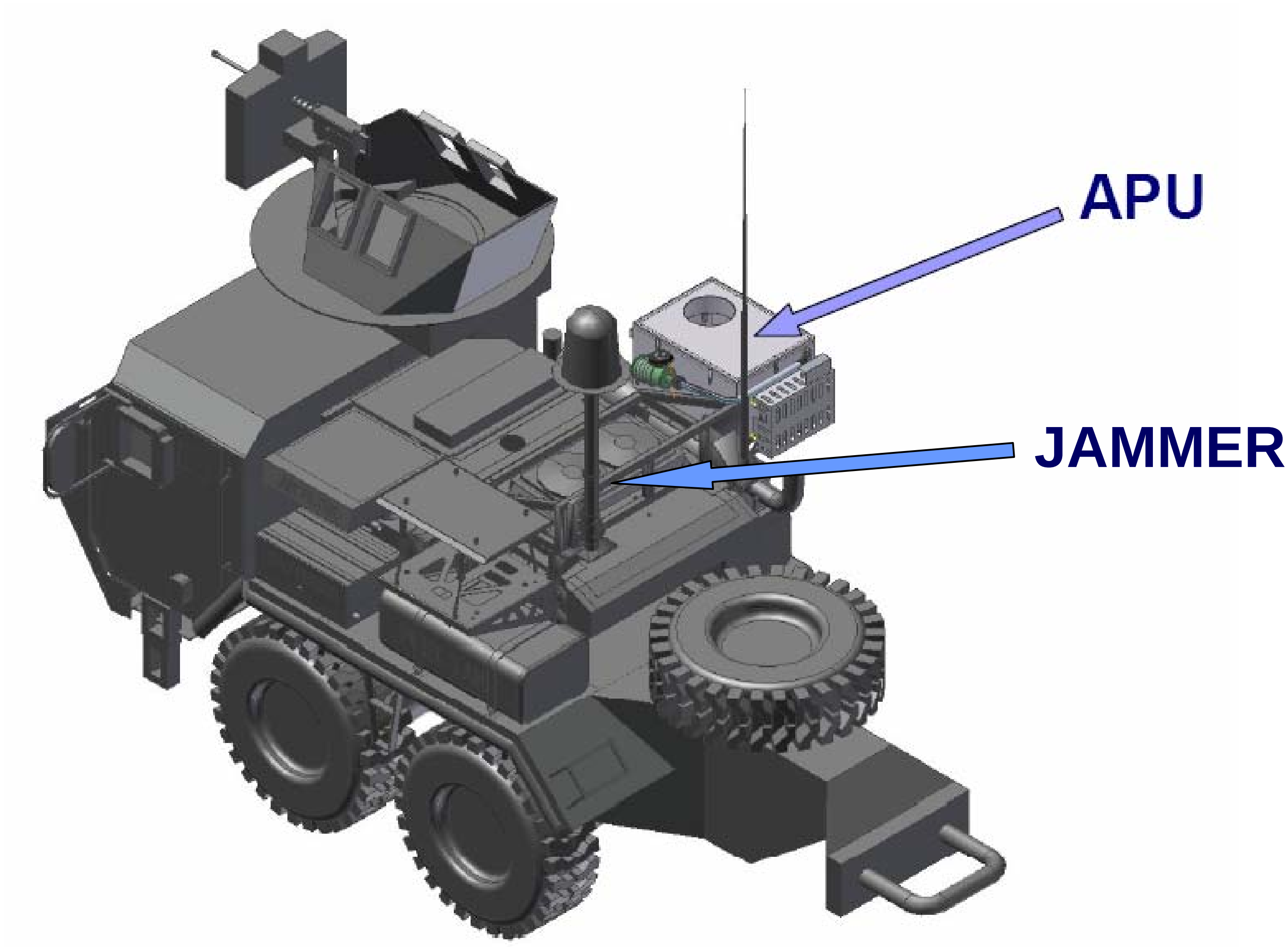
OBVP Schedule (HMMWV & MTVR)



On-Board Vehicle Power
Unique Applications

- Power community continually requested to support other platforms
    - Tanks
    - Logistics Vehicle System
    - HIMARS
    - Light Armored Vehicle
    - Lightweight 155 Howitzer
    - Amphibious Assault Vehicle
    - Force Protection / Military Police
- Continued need for power for Jammers, Silent Watch, stationary applications
- Necessary when host vehicle incapable of power load, or host vehicle can not be retrofitted with larger alternator
- 28 VDC Gensets needed (various sizes, ratings, restrictions)

On-Board Vehicle Power - Unique



Watch FedBizOpps for solicitations

On-Board Vehicle Power

Joint Service Power Exposition

25 April 2007

Briefings

- **Oshkosh Truck Corporation**
  - Nadr Nasr
  - Oshkosh Truck's Electric Drive approach to Mobile Power Platforms
- **ePower LLC**
  - William Henrickson
  - 30 kW On-Board Vehicle Power for the HMMWV
- **General Dynamics Land Systems**
  - Tom Trzaska
  - On-Board Vehicle Power for the HMMWV and MRAP
- **BAE Systems**
  - Stephen Cortese
  - Power Management and Mission Capability Integration for HMMWV

On-Board Vehicle Power

Joint Service Power Exposition

25 April 2007

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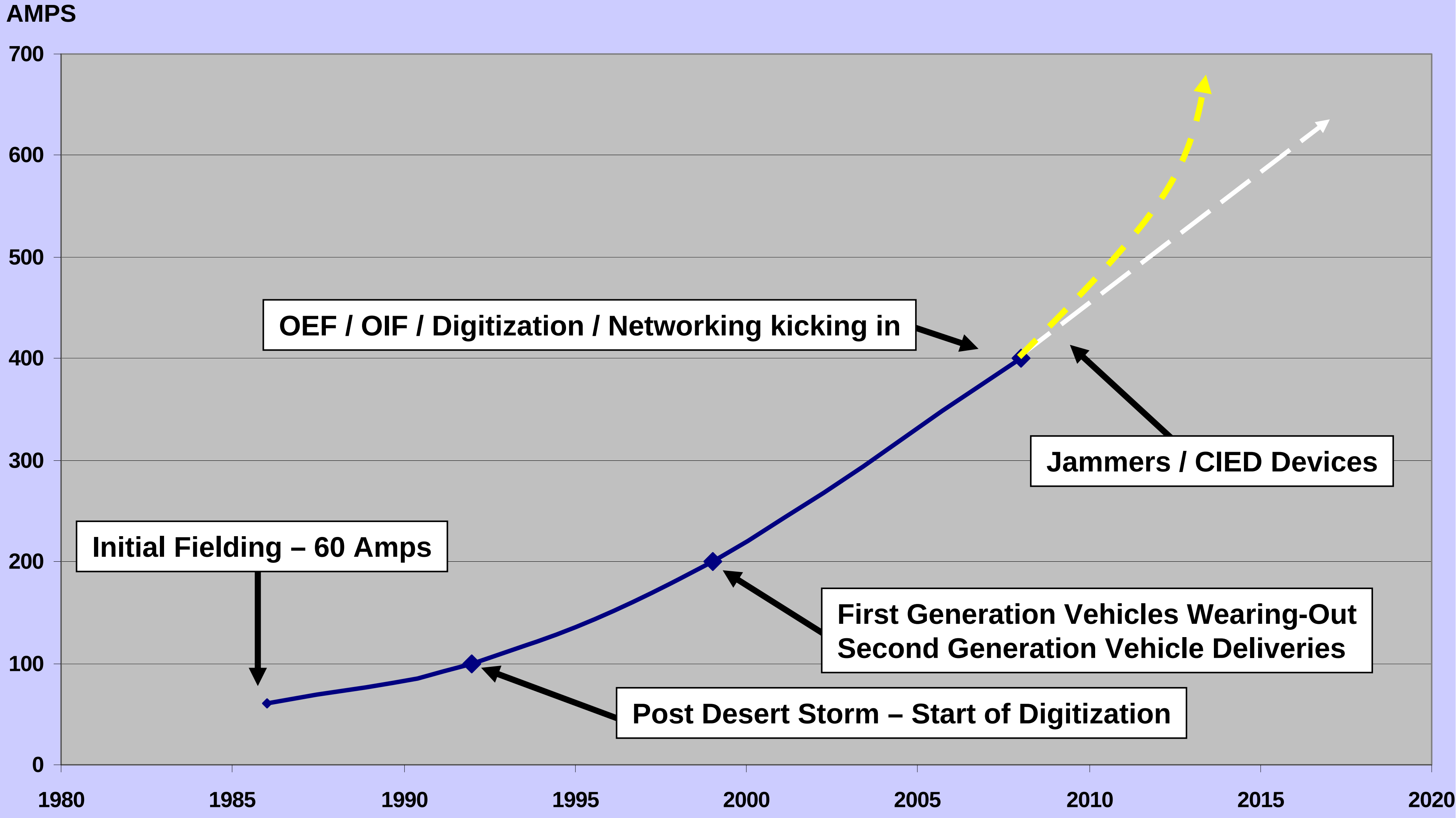
• William Henrickson	E-power
• Nadr Nasr	Oshkosh Truck Co
• Stephen Cortese	BAE Systems
• Tom Trzaska	General Dynamics

Alternator Amperage Rating on HMMWV at 28 VDC



2007 Joint Services Power EXPO 23-27 April 2007 San Diego, CA

Common Sense Approach to the Selection, Design/Fabrication, & Testing of Safe Operational Power Sources

Presented by
Robert Byrnes Sr.
Senior Battery Scientist
DHA Inc

Outline

Common Sense Approach

- Background
  - Bob's Terms/Advice
- Selection
- Design/Fabrication &
- Testing of Safe Power Sources
- Safety Testing of UltraLast AA Cells

BACKGROUND

MY PHILOSOPHY:

- USE A BATTERY ONLY IF NEEDED
- KISS
- USE COMMON SENSE
- FEEDBACK REQUIRED

EQUIPMENT PROBLEMS

THE CAUSES:

- ANTENNAES
- BATTERIES
- CONNECTORS

BATTERY / PORTABLE EQUIPMENT

AS

BULLET / GUN

BATTERIES
THE “ACHILLES HEEL”
OF
TECHNICAL OPERATIONS

Battery Bob's Mottos:

"Trust but verify"

Ronald Reagan

"Test everything;
retain what is good."

1 Thessalonians 5

PREMATURE BATTERY FAILURE CAN:

- CREATE LIFE THREATENING SITUATIONS
- RESTRICT COLLECTION INFORMATION

MOST BATTERY PROBLEMS ARE CAUSED BY PEOPLE WITH:

- **LITTLE OR NO INFORMATION**
- **MISINFORMATION**
- **LACK OF TRAINING/EXPERIENCE**

BATTERY BOB’S

TERMS/ADVICE

THE CAPACITY, ENERGY, POWER RELATIONSHIP

$E \neq P$

$$E_{Wh} = \underbrace{V_L(V) \times \rlap{$\overbrace{}^{C\,(Ah)}$}I_L(A)}_{P_L\,(W)} \times t(h)$$

L - load

THE CAPACITY, ENERGY, POWER RELATIONSHIP SYMBOLS

E = Energy (Work) (Wh)

P = POWER (W)

V = Voltage (V)

C = Capacity (Ah)

I = Current (A)

t = TIME (h)

L = load

AVOID BATTERY PROBLEMS BY:

- Checking Mfgr's Spec Sheet

  Note: No Standard Spec Sheet
- Buying from High Volume Stores
- Knowing Date Codes
- Screening (Primary) OCV & CCV
- Screening & Matching (Secondary)
- Using Common Sense

BATTERY BOB’S AXIOMS:

- THERE IS NO IDEAL CELL!
- ALL COMMERCIAL CELLS ARE ALWAYS UNDER DEVELOPMENT.
- KEEP BATTERY STASHES ROTATED & AVAILABLE TO ALL.
- DON’T MIX BATTERIES w/ BULLETS, COINS, or OTHER METAL ITEMS!

This is what happens if you do.

Name	Size	Chemistry	Temp °C	Temp °F
ECO	AA	$Li/SOCl_2$	113-121	235-250
ECO	AAA	$Li/SOCl_2$	94-106	201-223
Sanyo	CR-2N	Li/MnO_2	64-70	142-158
Tadiran	TL-2200 C	$Li/SOCl_2$	88	190
Tadiran	TL-2300 D	$Li/SOCl_2$	70-90	158-194
Blue Star	D	Li/MnO_2	50-116	122-241
Panasonic	BR-2/3A	Li/CF	149-151	300-304
Sanyo	HR-AA	Ni/MH	108-115	226-239
Sanyo	HR/4/3A	Ni/MH	73-75	163-167
Duracell	MX1500 AA	Zn/MnO_2	100	212
Sanyo	CR-2	Li/MnO_2	76	169
Duracell	DL2/3A	Li/MnO_2	91-93	196-199
Duracell	Ultra 123	Li/MnO_2	78-93	172-199
Duracell	LM 123A	Li/MnO_2	71-84	160-183

SECONDARY BATTERY CHEMISTRIES:

- **Nickel Cadmium-store discharged.**
- **Lead Acid-store charged.**
- **Nickel Metal Hydride-store discharged.**
- **Li-Ion-store 50% charged.**

- **Check out the equipment using the selected cell or battery instead of a DC power supply.**

- **The operation of equipment using a DC power supply may differ from the operation using other power sources.**

- **Where possible simulate the actual use regime as closely as possible.**

SELECTION

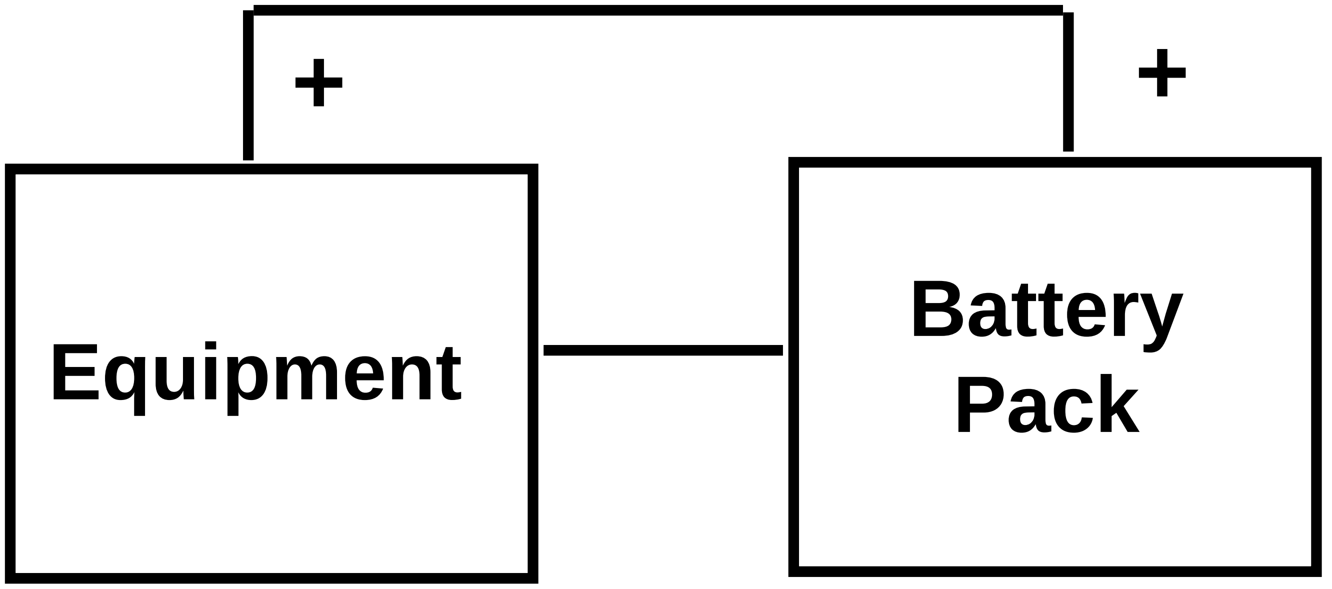
IF YOU WANT A BATTERY FROM ME PICK ONLY TWO BELOW:

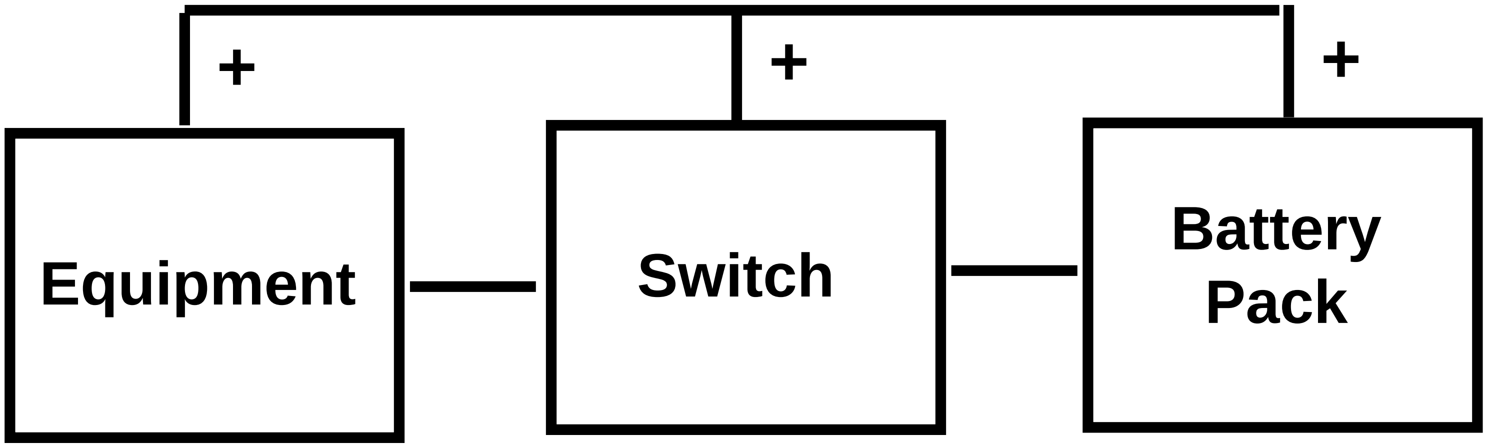
- QUICK
- CHEAP
- SMALL
- RELIABLE

Basic Tips for the User in the Selection of Batteries for Operational Use:

- Define your need as fully as possible.
- There is no ideal power source.
- Don’t make the choice of a power source a last minute decision.
- Keep the power source design simple.

TYPICAL BATTERY PACKS


+
+
Equipment
Battery
Pack


+
+
+
Equipment
Switch
Battery Pack

BATTERY

DESIGN/FABRICATION

CONSIDERATIONS

IF I DESIGN A BATTERY, SHOULD IT BE, A PRIMARY OR A RECHARGEABLE BATTERY?

IF I DESIGN A BATTERY, CAN I FABRICATE IT SAFELY? IN TIME?

IF I DESIGN A BATTERY, CAN I SHIP IT SAFELY? LEGALLY? IN TIME?

FOR LITHIUM BATTERY SHIPMENT QUESTIONS SEE YOUR SHIPPING OFFICER FOR GUIDANCE

WHAT DO I DO WITH THE BATTERY AFTER I HAVE FINISHED WITH IT???

CAN I DISPOSE OF IT SAFELY? LEGALLY?

FOR BATTERY
DISPOSAL QUESTIONS
SEE YOUR
SAFETY OFFICER
FOR GUIDANCE

APPLIED BATTERY DESIGN

SIMPLE APPLICATIONS

MAJOR DESIGN CONSIDERATIONS

1) **VOLTAGE**
2) **LOAD CURRENT**
3) **BATTERY LIFE**
4) **SIZE AND WEIGHT**
5) **ENVIRONMENTAL REQUIREMENTS**
6) **SAFETY VENTING**
7) **SAFETY FUSING**
8) **LAYOUT OF PACK TO REDUCE IR LOSSES**
9) **LAYOUT OF PACK TO REDUCE I^2R LOSSES**
10) **DIODE ISOLATION**
11) **CONNECTORS**
12) **LOW VOLTAGE CUTOFF FOR SOME Li CELLS**

MAJOR DESIGN CONSIDERATIONS VOLTAGE

- The devices with which the batteries are used have limitations on the maximum and minimum voltages between which they will work properly.
- The devices may also have limitations on the maximum voltage beyond which they will be permanently damaged.
- There might also be limitations on the minimum voltages below which they will have to be “reset”.
- Does the device perform consistently over the voltage range?
- Is there a preferred voltage?
- Are there multiple voltages required in one pack?

MAJOR DESIGN CONSIDERATIONS VOLTAGE

- Batteries have maximum, minimum, and typical voltages. How do these match with the device requirements?
- If the battery's operating voltage range does not match the requirements of the device being powered, an electronics package may be needed to regulate the voltage. Otherwise, the full capacity of the battery might not be useable.
- An electronics package might also be needed to control the charging of the battery.

MAJOR DESIGN CONSIDERATIONS *CURRENT*

- Affects the life of the battery
- Affects the size of the wiring in the pack and connectors
- Continuous high load current may have a thermal impact
- What is the nature of the current? Is it pulse? Continuous? A mixture of both?

MAJOR DESIGN CONSIDERATIONS
CURRENT

PEAK CURRENT

- The voltage and capacity available from a battery is affected by the discharge current.
- As the current increases, the voltage decreases.
- As the current increases, the amount of capacity that the battery can deliver decreases.
- At some currents, the battery will not produce a usable voltage.

MAJOR DESIGN CONSIDERATIONS
CURRENT

PEAK CURRENT

- EVALUATE PRIMARY vs. SECONDARY
- Primary - good energy density (energy measured in Wh)
- Secondary - good power density (power measured in watts)
- Hybrid - utilize the best characteristics of each *(but with added complications)*

MAJOR DESIGN CONSIDERATIONS
CURRENT

AVERAGE CURRENT

- The number of Ampere-hours that are required is determined by the average current consumed by the device being powered.
- If an average current is not known, it can be calculated from the individual loads, the currents during all operating conditions, and the duty cycle.

MAJOR DESIGN CONSIDERATIONS
LIFE

How Long Before The Battery Can Fail?

- *Shelf Life*
  - How long must the battery be available before the device operating time starts?
- Operating Life
  - How long must the battery power the device?
- What about End of Life?
  - How Will The Battery Be Shut Down?

MAJOR DESIGN CONSIDERATIONS *LIFE*

SHELF LIFE

- Effects of self discharge on battery life.
- Passivation - high initial pulse need.
- Cell seals - different seals start to leak at different times.
- Storage time before operation.
- Battery maintenance during storage.
  - Some chemistries need to be kept charged lead acid
  - Some chemistries have “memory effects”

MAJOR DESIGN CONSIDERATIONS *LIFE*

OPERATING LIFE

- Effects of discharge current on useable battery capacity.
- Effects of temperature on useable battery capacity.

MAJOR DESIGN CONSIDERATIONS
SIZE & WEIGHT

CAN THE BATTERY BE CONCEALED?

- Will the weight give it away? *Too heavy or too light?*
- Will the size give it away? *Too big?*
- Will it fit in the electronics package? *Wrong shape?*
- Certain chemistries swell upon discharge.
- If a cell should go bad, is there enough capability left in the other strings to handle the mission?
  - Often a trade-off of size/weight versus redundancy.

MAJOR DESIGN CONSIDERATIONS
ENVIRONMENTAL REQUIREMENTS

- The performance of a battery is affected by the environment in which it will be used.
- Temperature has an impact on the battery.
  - Useable capacity.
  - High power pulses.
  - Function & Survivability
- The performance and battery design can be affected by other factors
  - Will the battery need to be moved?
  - How will it be moved
    - Road vehicle, Aircraft - Passenger/Cargo, Camel, Etc.
- Worldwide use? Indoor use? Outdoor? Tactical? Jungle? Desert? Snow? Salt fog?

MAJOR DESIGN CONSIDERATIONS *THINGS TO PONDER*

- SAFETY VENTING
  - If a cell should vent, a path for the escaping gases needs to be provided
  - How does this impact on the mechanical design of the electronics package?
- SAFETY FUSING
  - Depends on cell chemistry and/or # of cells

MAJOR DESIGN CONSIDERATIONS
PACK LAYOUT TO REDUCE LOSSES

- HEATING LOSSES = I^2R
- VOLTAGE LOSSES = IR
  - Length and size of wiring in the pack
  - Cell interconnects and location
- DIODE ISOLATION
  - Parallel strings of cells need to be diode isolated
  - Voltage drop across diodes
- CONNECTORS
  - Size and type
  - Wire leads?

MAJOR DESIGN CONSIDERATIONS *REFINING THE CHOICES*

- Verify cell selection will meet Operational Requirements

- **Electrical**
- **Environment**
- **Size and Weight**
- **Transportation**
- **Delivery Schedule**
- **Redundancy**
- **Reliability**
- **Cost**
- **Safety**
- **Further trade-offs**

MAJOR DESIGN CONSIDERATIONS
CELL SELECTION

NOT ALL CELLS PERFORM THE SAME

- This is true for:
  - Different chemistries
  - Same chemistries, but different manufacturers
  - Same chemistry and manufacturer, but different sizes
  - Same chemistry and manufacturer, but different manufacture date
- Not all cells are equally predictable or reliable in their performance.

PERFORMANCE
RELATIVE TO MODEL

Different versions of cells give different performance characteristics

Even if they are the same chemistry, manufacturer and size

PERFORMANCE
RELATIVE TO MANUFACTURING DATE

Cell manufacturers change the way cells are built. A cell built one year may be different from another year.

There are many reasons:

- **Cost/Profit**
- **Competitive performance**
- **Build-to-build variation**

PERFORMANCE
RELATIVE TO SIZE

Different size cells give different performance characteristics

Even if they are the same chemistry, manufacturer and general construction (i.e. prismatic, bobbin, spiral wound).

PERFORMANCE RELATIVE TO CHEMISTRY

Different chemistry cells give different performance characteristics.

Even if they are the same size, the chemistry has different characteristics associated with it.

There may be construction differences as well. These may be needed by the nature of the chemistry (Different materials in the can, etc.)

PERFORMANCE RELATIVE TO CUT-OFF VOLTAGE

The amount of Capacity that a cell can deliver can be greatly affected by how low a voltage that the cell can be discharged and still do useful work.

This can be affected by both discharge rate and temperature.

Low voltage cutoff a must for some high powered lithium batteries to prevent reversal.

MAJOR DESIGN CONSIDERATIONS
CELL AVAILABILITY

- **Forward Deployed**
- **Warehouse**
- **Contractor Stockpile**
- **Commercial Purchase**
- **Special Purchase**

MAJOR DESIGN CONSIDERATIONS
CELL LEVEL TESTING

- Qualification Testing
- Lot Acceptance
- Screening
- Specialized testing
  - Environmental
  - Mission Profile
  - Safety

MAJOR DESIGN CONSIDERATIONS
BATTERY LEVEL TESTING

- Environmental
- Safety
- Mission Profile
- Qualification
- Screening

BATTERY PROGRAM CHECK LIST

ELECTRICAL REQUIREMENTS

1. Max. No Load Volts: ______________ V
2. Steady-State or No-Pulse Load Data:
   - Max Volts: ______________ V
   - Min, (CUTOFF) Volts: ______________ V
   - Current at Max. Volts: ______________ V
   - Current at Min. Volts: ______________ V
3. Pulse Load Data (IF APPLICABLE):
   - Duration of Pulse: ______________ msec
   - Frequency of Pulses: ______________
   - Max. Volts ______________ V
   - Min. (CUTOFF) ______________ V
   - I @ Max. Volts (PEAK): ______________ mA
   - I @ Max. Volts (AVE.): ______________ mA
   - I @ Min. Volts (PEAK): ______________ mA
   - I @ Min. Volts (AVE.): ______________ mA
4. Duty Cycle: ______________ Hrs On-Off/Week
5. Service:
   - Actual On Time (MEDIAN): ______________ h
   - Electrical Capacity: ______________ Ah
   - Storage Time Prior to Use (MAX.): ______________ h
   - Total Unit Life (Max.) ______________ h

PHYSICAL REQUIREMENTS

1. Size if Prismatic:
   - Length: ______________ mm/in
   - Width: ______________ mm/in
   - Height: ______________ mm/in
2. Size if Cylindrical:
   - Diameter: ______________ mm/in
   - Height: ______________ mm/in
3. If Irregular Size, Specify: ______________
3. Weight: ______________ g/oz
4. Position of terminals (TOP OR SIDE): ______________
5. Submit Drawing (IF APPLICABLE) of Device Housing Cells/Battery Pack. (USE BACK OF SHEET FOR DRAWING.)

ENVIRONMENTAL REQUIREMENTS

(Note: The electrical requirements presume a temperature of 24 °C (75 °F). It is desirable to specify the electrical requirements at the maximum and minimum temperatures expected.)

1. Storage:
   - Expected Temp. Range: ______________ °C/°F
   - Expected Avg. Temp.: ______________ °C/°F
   - Expected Humidity Range: ______________
   - Expected Avg. Humidity: ______________
2. Use:
   - Max. Temp: ______________ °C/°F
   - Min Temp.: ______________ °C/°F
   - Expected Temp.: ______________ °C/°F
   - Expected Humidity Range: ______________
   - Expected Avg. Humidity: ______________
3. Shock and Vibration: ______________
4. Applicable Specifications: ______________
5. Other: ______________

OTHER REQUIREMENTS

1. Reliability: (What Minimum Capacity is Desired at What Confidence Level?)
   ____
2. Battery Disposal: ______________
3. External Signature: ______________
4. Transportation: (Very Important For DOT Regulated Power Sources.) ______________
5. Delivery Schedule (Include Testing): ______________
6. Operation Scenario(s) – (Be As Specific as possible. Use separate sheet for details if necessary. Classify appropriately.) ______________
   ____
   ____

FOR RECHARGEABLE POWER SOURCES ONLY

1. Desired Charge-Discharge Cycles: ______________
2. Depth of Discharge (DOD) ______________ %
3. Minimum Charging Time: ______________ h
4. Normal Charging Time: ______________ h
5. Charging Modes:
   - Constant Current: ______________
   - Current Trickle: ______________
   - Constant potential: ______________
   - Constant Potential (FLOATING): ______________
6. Types of Use:
   - Frequent: ______________ h/week
   - Standby: ______________ h/week
7. Charging Temp Range: ______________ °C/°F
8. Other Charging/Charger Info:
   ____

MSDS

Material Safety & Data Sheet
Important if the cells in your battery go south.

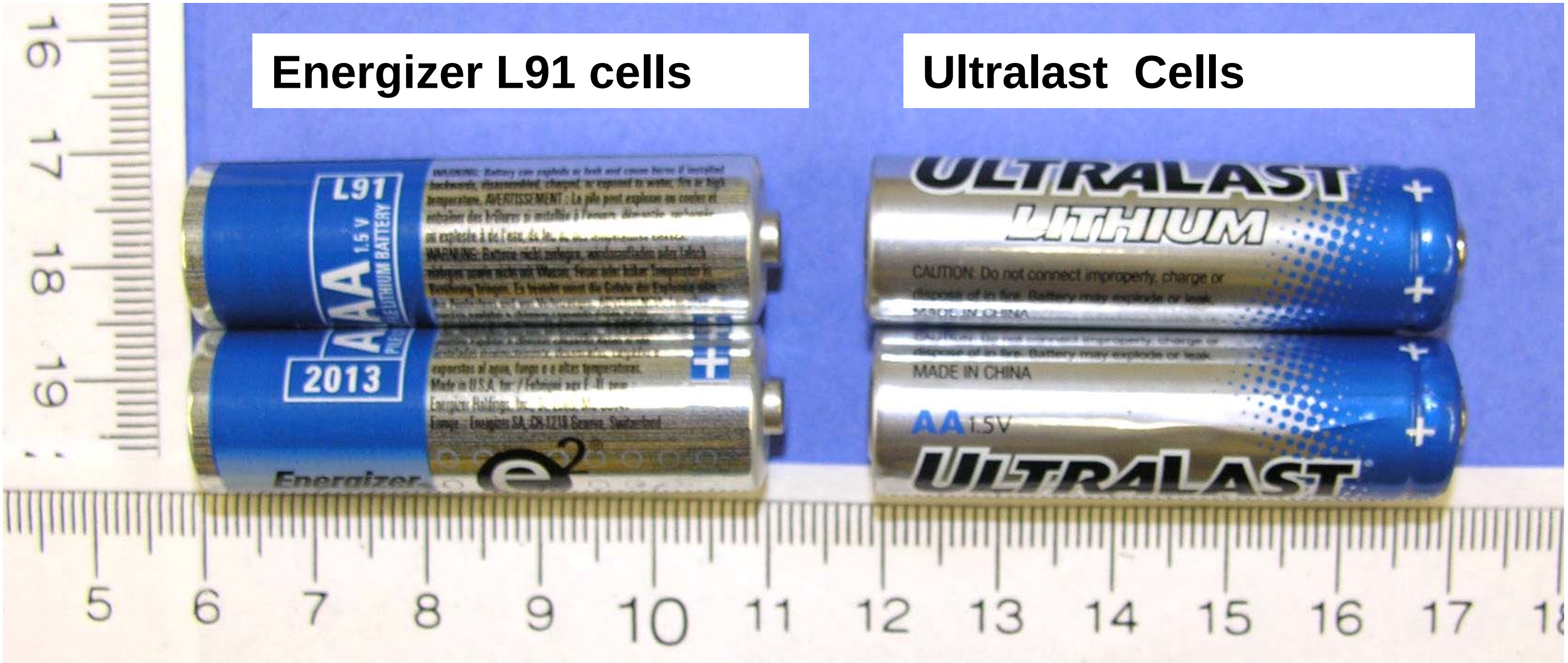
ULTRALAST Li/FeS2 AA CELLS

Circa 2006

Background Info

Chinese made AA Lithium Iron Disulfide (Li/FeS2)cells were shipped to the US and sold under the Ultralast label. The Ultralast label was very similar in appearance to the label Energizer uses for its Li/FeS2 AA cell Comparative Safety Testing was done on both the Energizer and Ultralast Li/FeS2 cells.

Introduction



Introduction

UN TESTING
of
Energizer
&
Ultralast
AA Cells

UN TEST #5:
External Short Circuit Test

- Six (6) undischarged Ultralast cells were subjected to a short circuit test of less than 100 milliohms while maintained at 55 °C.
- The output voltage, current, and skin temperature were continuously monitored during the test.
- The short circuit condition was maintained for a minimum period of one (1) hour after the cell skin temperature had returned to 55 °C. The cells were observed for an additional period of six (6) hours.

UN Test #5:
External Short Circuit Test Results

- The highest maximum short circuit current was 10.47 amps, while the lowest was 6.54 amps.
- Two cells exhibited fire, with flames emanating from the positive end vent holes, the first cell at 2 hours, 31 minutes, and the second cell at 3 hours, with enough pressure release to pop the oven door open, and temperatures exceeding 170 °C (i.e. 341 °C, and 355 °C). The other four (4) cells oozed a tan colored material from the positive end, and two (2) of them reached 134 C.

Results-Comparison UN Test #5: External Short Circuit Test

- The Energizer L 91 cells, (with 10 cells tested under the same conditions), reached a highest maximum short circuit current of 14.13 amps, while the lowest was 12.57 amps.
- The highest skin temperature reached by any of the cells was 97 °C. None of the cells exhibited fire, rupture, disassembly, or temperature exceeding 170 C.

UN TEST #6: Impact Test A Lot of Reaction #4 Cell.

Five (5) undischarged Ultralast cells were subjected to the United Nations Impact Test (Test # 6)

The cell under test rested upon a Pine wood “flat surface”, measuring 5 - 1/2 inches X 5 - 1/2 inches X ¾ inch thick. A 5/8 inch diameter hardwood dowel “bar” rested upon the center of the cell, such that the “bar” was perpendicular to the longitudinal axis of the cell and parallel to the “flat surface”. A 20 pound mass was allowed to fall a distance of 24 inches before impacting the “bar”.

UN TEST #6: Impact Test Cont’d.

Upon impact, and for a six (6) hour observation period thereafter, the first three (3) cells demonstrated no evidence of fire, disassembly, or temperature exceeding 170 °C. The highest temperature achieved by any of those cells was 27 °C.

UN TEST #6: Impact Test Cont'd.

The fourth (4th) cell, at 30 seconds after impact, reacted with the ejection of the positive end cap, followed by the violent expulsion of fire and burning material from the positive end (some of which penetrated the aluminum screen), thus, meeting the definition of disassembly. During the period of burning, the cell skin temperature rose to 601 ºC.

The fifth (5th) cell, upon impact, and for a six (6) hour observation period thereafter, reacted the same as the first three cells.

UN TEST #6: Impact Test Cont'd.-Comparison

Previously, the Energizer L91 cell had five (5) cells subjected to the Impact Test.

Upon impact, and for a period of six (6) hours thereafter, there was no evidence of fire, or disassembly, and the maximum case temperature achieved by any of the cells was 95 °C (maximum allowed = 170 °C). Although the end caps were dislodged, they did **not** penetrate the aluminum screen. Therefore, the cells did **not** meet the definition of disassembly.

UN TESTS #5 & #6: Conclusions:

- Ultralast Li/FeS2 cells failed UN Tests #5 & #6.
- Energizer Li/FeS2 cells did not fail UN Tests #5 & #6.
- Cells which do not meet UN Tests should not be imported into the US for sale.
- The Ultralast AA Li/FeS2 cells are no longer being sold in the US but other Chinese AA Li/FeS2 cells are available on the Internet.

Note: 49 CFR 171.12 (a) Battery Importers

"Each person importing a hazardous material into the US shall provide the shipper and the forwarding agent at the place of entry into the US timely information on the requirements of the regulations that apply to the shipment."

SAFETY TESTING VIDEO of ULTRALAST Li/FeS_2 AA Cells

Contact Information

DOD Project Manager Mobile Electric Power

Mobile Electric Power
for
Today and Tomorrow

Joint Service Power Expo
25 April 2007

Paul Richard
Acting DOD Project Manager Mobile Electric Power

Presentation Outline

- PM MEP Organization/Systems
- Requirements & Challenges
- Major Initiatives
- Technology Thrusts

PM MEP Organization

DOD Project Manager
Mobile Electric Power
Mr. Paul Richard (Acting)

Deputy Project Manager
Mr. Alan Coady

Logistics Division
Mr. Alan Coady

Engineering Division
Dr. Eric Parrish

Business Management
Ms. Lisa Denning

Product Manager
Small Power Sources
LtCol Tom Bowers
USMC

Product Manager
Medium Power Sources
LTC John Kelleher
USA

Product Manager
Large Power Sources
LTC John Kelleher
Acting
USAF Position
to be filled May 2007

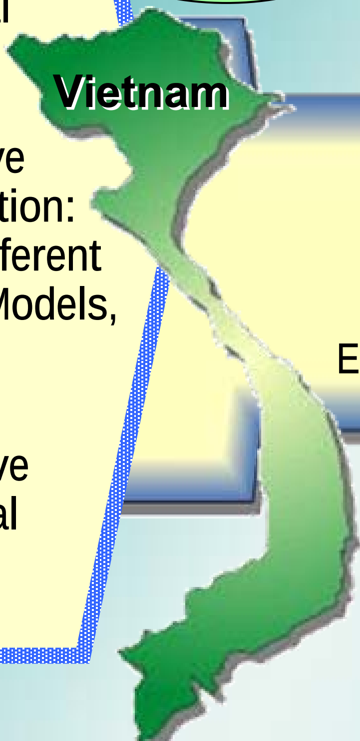
Mobile Electric Power History

Exorbitant Demand for Electrical Power

Excessive Proliferation: 2,000 Different Makes, Models, Sizes

Ineffective Logistical Support

1965
Southeast Asia



1967
DOD Ad Hoc Working Group Established

Developed

PM-MEP *Mission*

DoDD 4120.11

"Establish, Maintain and Provide a DOD Standard Family of Generating Sources for Maximum DOD Component Use"

U.S Army Designated as Lead Standardization Activity

Established

PM-MEP CHARTER

DOD Project Manager - Mobile Electric Power PM-MEP

JOP
Joint Operating Procedures

Joint Operating Procedures Management and Standardization of Mobile Electric Power Generating Sources

Army Regulation 700-101
AFJI 63-110
NAVFACINST 4120.12
MCO 11310.8C
DLAI 4120.11

DFAR Requirement for PM MEP Approval for Non-standard Power Equipment

Military vs. Commercial

No Commercial Generator Set Meets Military Worldwide Requirements*

All Tactical Electric Power Generator Sets are Made from Commercial Components

Critical Military Features

- **Diesel/JP-8 (DoD Policy)**
- **Operate at all Environmental Extremes**
- **Excellent Power Quality**
- **High Reliability**
- **Battlefield Mobility**
- **Ruggedized**
- **24 Volt**
- **Enhanced Battlefield Survivability**
  - **NBC**
  - **IR**
  - **Aural**
  - **EMP Hardening**
- **Rated Power at Altitude**
- **Organically Supported**

Multi-Fuel
-50°F to +120°F
Mil Std 1332
RAM
Militarization
EMI
HFE

\>

Less Cost
Less Weight
Less Capable

\>

*** Market Surveys; 1989; 1999, 2003**

Mobile Electric Power Managed Items

Small Sets

- 2kW Military Tactical Generator, Manportable/Skid Mounted, Diesel/JP8 Fueled, AC(60Hz) and DC(28VDC)
- 3kW Tactical Quiet Generator, Skid Mounted, Diesel Fueled (60 Hz and 400Hz)


Medium Sets

- 5kW, 10kW, 15kW, 30kW, and 60kW, Skid Mounted, Diesel Fueled Tactical Quiet Generator, 60Hz and 400Hz
- AMMPS – Advanced Medium Mobile Power Sources



Large Sets

- 100kW and 200kW Tactical Quiet Generator (TQG), Skid Mounted, Diesel Fueled, 60Hz
- 840kW Deployable Power Generation and Distribution System (DPGDS), Diesel Fueled


Power Unit/Power Plant (PU/PP)

- Trailer Mounted Tactical Quiet Generators in the 3kW, 5kW, 10kW, 15kW, 30kW, 60kW, 100kW, and 200kW Power Ratings.
- 20 Different Models That Use 4 Different But Standardized TACOM Trailer Models


Power Distribution Illumination System Electric (PDISE)

Man-portable, Reliable, Modular, Quick Assembly Standardized Electrical Management and Distribution System Components

40 AMP/PHASE DISTRIBUTION SYSTEM
60 AMP DISTRIBUTION SYSTEM
100 AMP/PHASE FEEDER SYSTEM
200 AMP/PHASE FEEDER SYSTEM
UTILITY RECEPTACLE AND LIGHTING KIT

HI-POWER

Hybrid Electric Intelligent Power Management

Develop a Tactical Hybrid–Electric Power System for use at Forward Operating Bases to minimize logistics fuel consumption related to power generation.

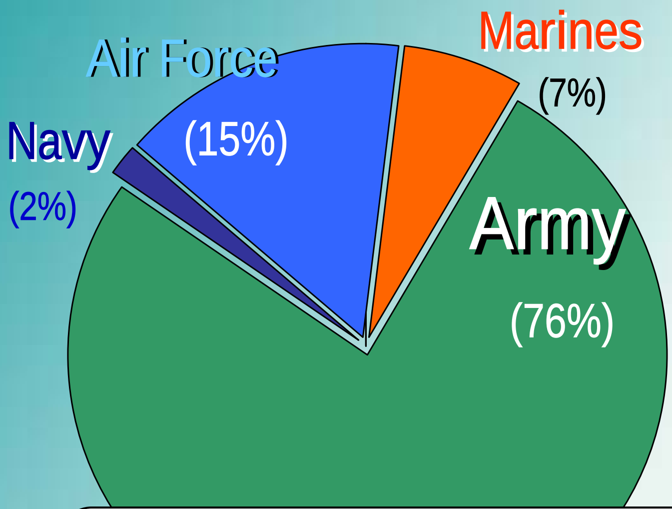

Improved Environmental Control Units (IECU)

New Generation of ECUs Utilizing Zero Ozone Depleting Refrigerants. Ruggedized Form, Fit, and Function Replacement Systems with Embedded Diagnostics.

9K, 18K, 36K, and 60K BTUH sizes.

Requirements
and
Challenges

Department of Defense
Tactical Electric Power Requirements



Size	Army # Req'd*	% Army Total	Qty Fielded	% Size Fielded
2kW	9,576	14%	8,609	90%
3kW	19,122	29%	9,901	52%
5kW	14,779	22%	9,143	62%
10kW	12,001	18%	9,189	77%
15kW	4,370	7%	3,186	73%
30kW	3,085	5%	2,623	85%
60kW	2,950	4%	1,826	62%
100/200/DPGDS	568	1%	25	4%
	66,451		44,502	67%

* BOIP05

MIL-STD = Military Standard
First Generation Gasoline and Diesel Engine Generator Sets

TQG = Tactical Quiet Generator
Second Generation, Modernized, Diesel Engine Generator Sets

2kW thru 840kW Generator Sets

Requirements		Fielded MIL-STD	Fielded TQG
Army	66,451	21,949	44,502
Navy	1,540	676	864
Air Force	13,340	3,451	9,889
Marines	6,552	0	6,552
Total	87,883	26,076	61,807

Data Thru Feb 07

Current Army Priorities

- GWOT
- TOC Central Power
- Modularity
- Modernization

Tactical Electric Power
Families / Generations

Department of Defense *Standard Family* of Mobile Electric Power Generating Sources

MIL-STD
Military Standard

Aging, *First* Generation DOD Standard Family of Mobile Electric Power Generating Sources

- 37 Generator Set Models
- Sizes 0.5kW Through 750kW
- Gasoline, Gas Turbine, and Diesel Engines

TQG
Tactical Quiet Generators

Modernized, *Second* Generation DOD Standard Family of Mobile Electric Power Generating Sources

- 18 Generator Set Models
- Sizes 2kW Through 920kW
- All Diesel Engines
- R&D On-going for Some Models

Next Generation
Power Sources

AMMPS
Advanced Medium Mobile Power Sources

12 Generator Set Models

5kW through 60kW Sizes

Procurement 2009

LAMPS
Large Advanced Mobile Power Sources

100kW through 1mW Sizes

Procurement TBD

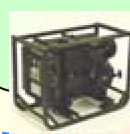
STEP
Small Tactical Electric Power

Less Than 3kW Sizes

Procurement ~2013

- **Leverage Commercial Technologies**
- **Minimize Number of Sizes and Models**
- **Use Proven Technologies**
- **Replace Entire DOD Generator Fleet Approximately Every 15 Years**
- **Maximize Competition**

Average Annual Cost Per Generator **$13,347**



Average Annual Cost Per Generator **$9,582**

AMMPS Projected Average Annual Cost Per Generator **$8,143**

Next Generation

TQG (Tactical Quiet Generator)

MIL STD (Military Standard)

1965	1970	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025

Improved Environmental Control Units (IECU) Requirements

IECU Procurement Quantities

9K	(115V, 1PH, 50/60Hz)	3,180
18K	(230V, 1PH, 50/60Hz) and (208V, 3PH, 50/60Hz)	3,767
36K	(208V, 3PH, 50/60Hz)	1,577
	Army Total	8,524

60K (208V, 3PH, 50/60Hz)	Army	4,960
	Air Force	787
	Total	5,747

Unvalidated Requirements

- TOCs
- JNN
- Patriot
- UAVs
- Others

IECU Challenge
(Improved Environmental Control Unit)

- Approximately 17,800 MIL-STD ECU Systems currently fielded in sizes 9k, 18k, 36k and 54k BTUH
- Current ECUs do not comply with the Clean Air Act 2010 Mandate for Ozone Depleting Refrigerants
- IECUs will comply with EPA Clean Air Act
- Only 60k BTUH IECU currently funded
- 9k, 18k, 36k BTUH IECUs funded for development
  - Procurement funding to be added in FY10-15 POM

Electronic systems will overheat and fail without the critical cooling ECU’s provide

Major Initiatives

TOC Central Power & Power Assessment

What it Is

Program to Assess and Optimize the use of Tactical Electrical Power Production and Distribution in the Field

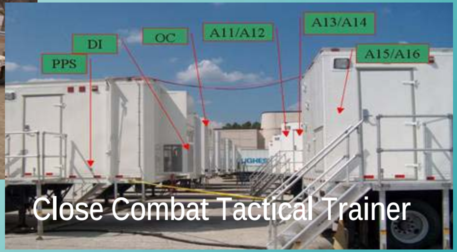
What it Does

- Significantly Reduces Logistics Footprint
- Increases Operational Availability
- Reduces Fuel Consumption
- Reduces Transportability Requirements
- Determines Most Efficient Use of Resources

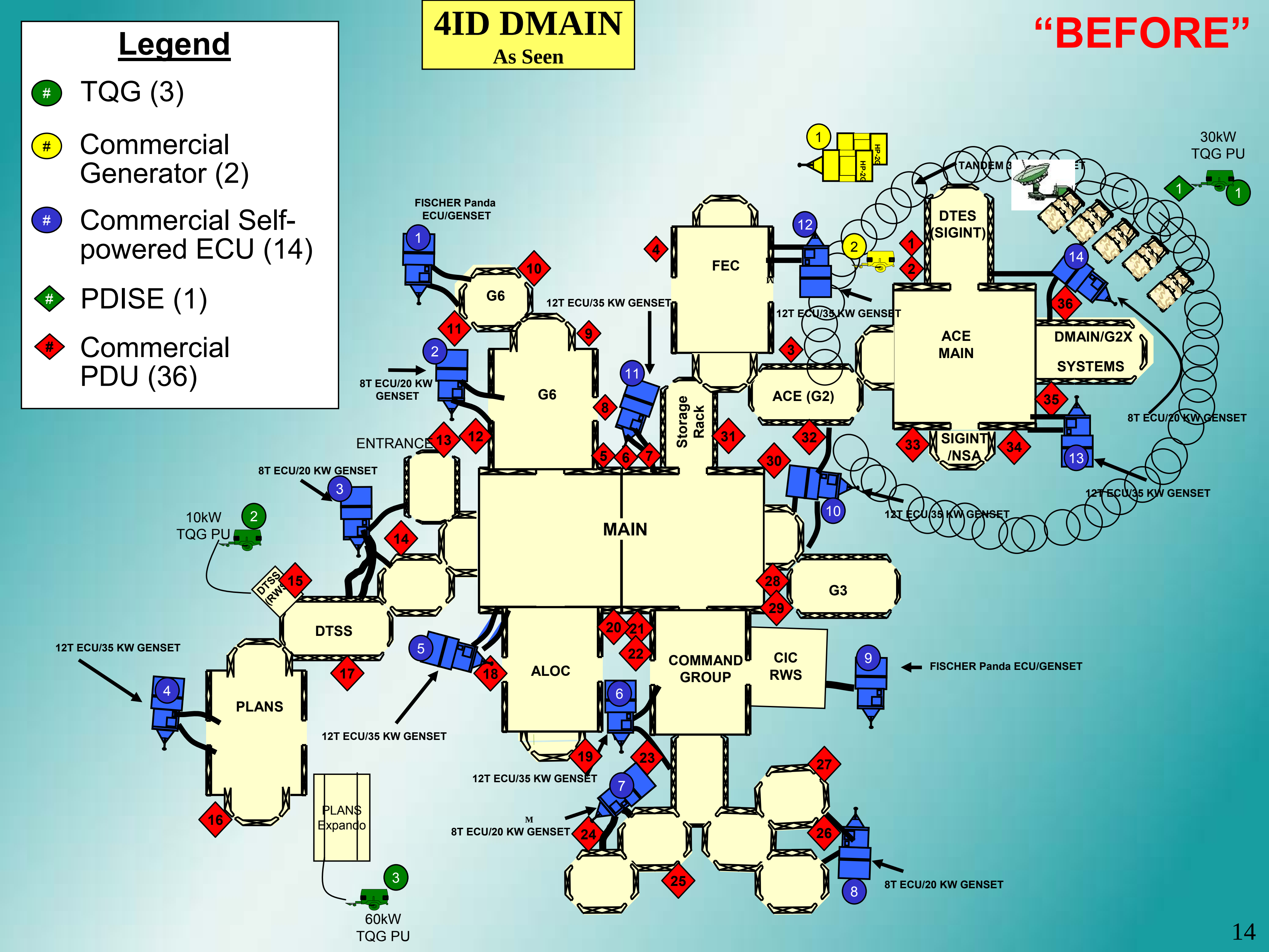
Consolidates Power Sources in TOCs

Provides Back-up for Mission Critical Systems

Decreases Logistics Footprint of TOCs



"Right Number and Right Size Generator Sets"



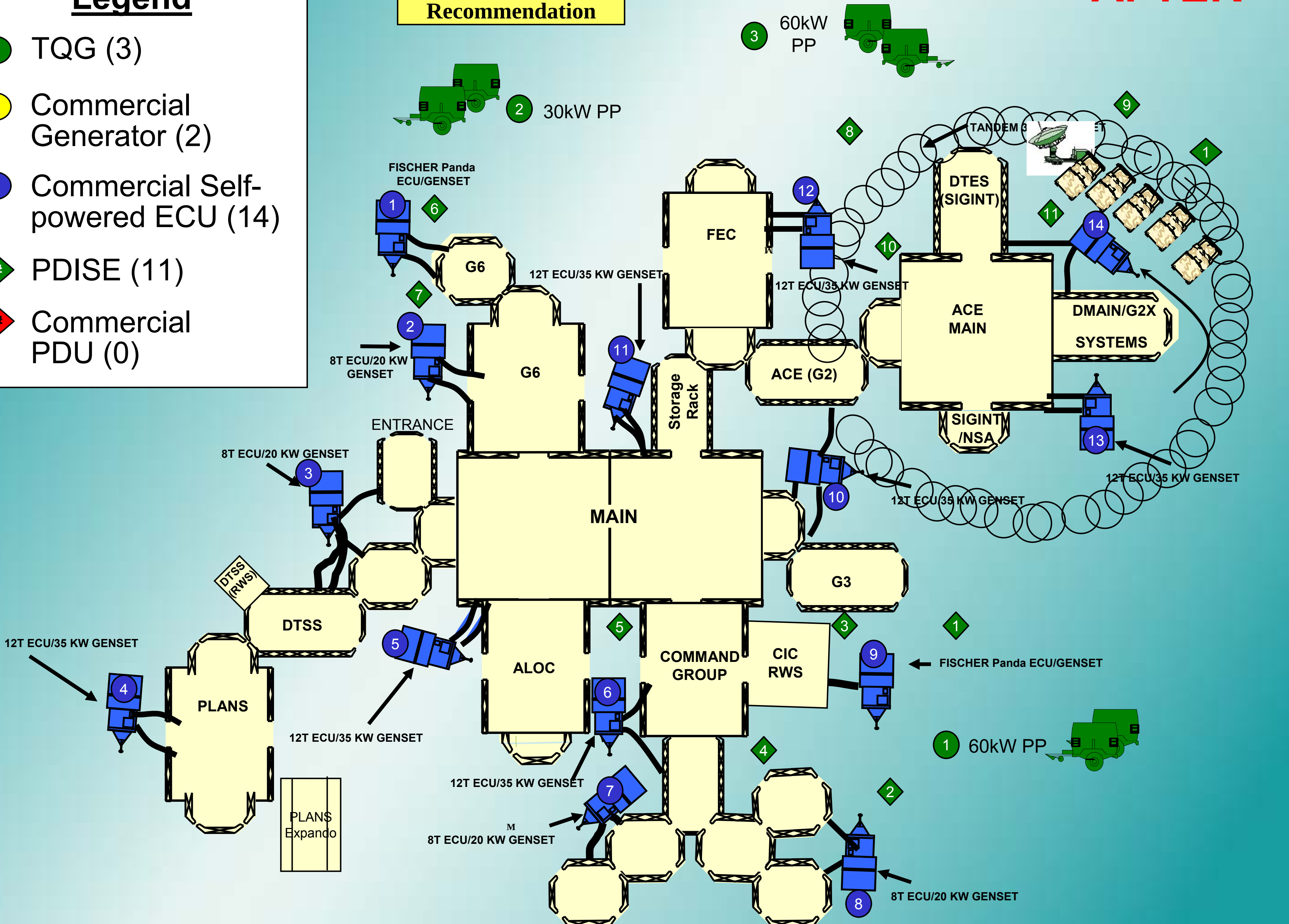
4ID DMAIN
As Seen
"BEFORE"
Legend
TQG (3)
Commercial Generator (2)
Commercial Self-powered ECU (14)
PDISE (1)
Commercial PDU (36)
FISCHER Panda ECU/GENSET
G6
12T ECU/35 KW GENSET
FEC
DTES (SIGINT)
30kW TQG PU
8T ECU/20 KW GENSET
ENTRANCE
Storage Rack
ACE (G2)
ACE MAIN
DMAIN/G2X SYSTEMS
SIGINT /NSA
MAIN
G3
10kW TQG PU
DTSS (RWS)
DTSS
PLANS
ALOC
COMMAND GROUP
CIC RWS
PLANS Expando
60kW TQG PU

4ID DMAIN
Recommendation

"AFTER"

Legend

- TQG (3)
- Commercial Generator (2)
- Commercial Self-powered ECU (14)
- PDISE (11)
- Commercial PDU (0)



Power Assessment
Benefits and Savings

Optimized power grid for:

- Soldier safety
- 24/7 operation of mission-critical equipment
- Better reliability, supportability and readiness
- Minimum footprint and increased transportability
- Reduction of Non-standard Commercial Hardware
- Organic Support by Soldiers

When Central Power Design Applied to 4ID Main TOC MTOE, Savings are:

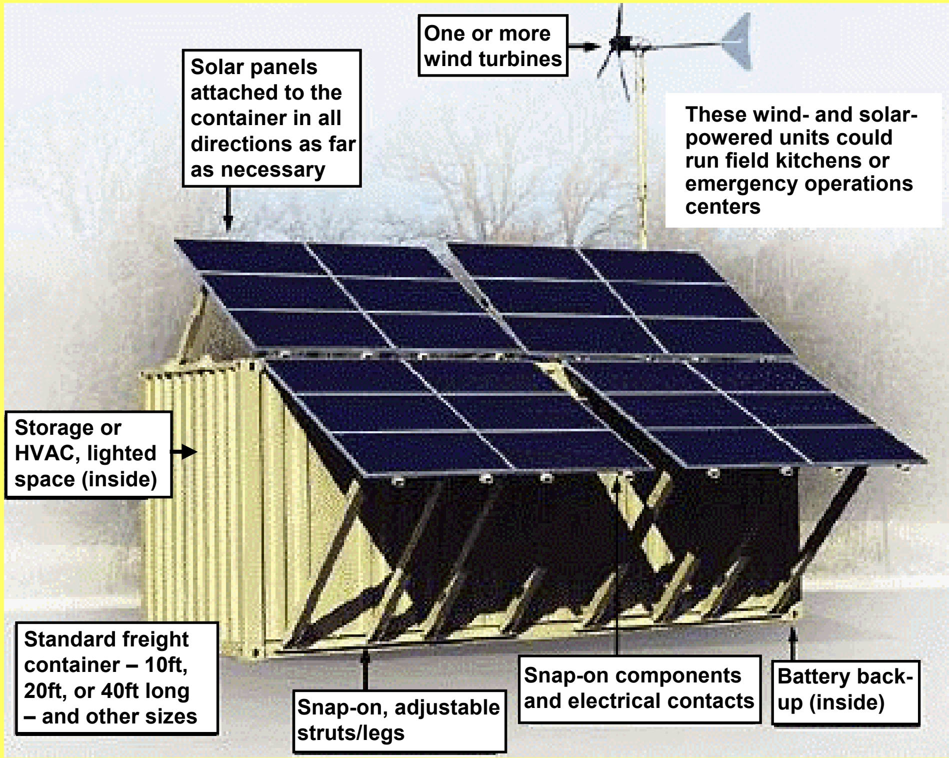
• Generator Sets	**11**	
• Fuel Reduction	**~ 200 gal/day**	
• Weight	**23,353 lbs (~ 12 tons)**	
• Volume	**4,735.2 cu ft**	
• Reduced Pintle Requirement	**HMMWV**	**5**
	FMTV	**3**
• First Year Savings	**$384,146.35**	

Not Including Savings for Reduced Contractor Field Support

HI-POWER
Hybrid Electric Intelligent Power Management

3kW Hybrid Electric System

SkyBuilt Hybrid Electric System



Develop a tactical hybrid-electric power system for use at Forward Operating Bases to minimize logistics fuel consumption related to power generation.

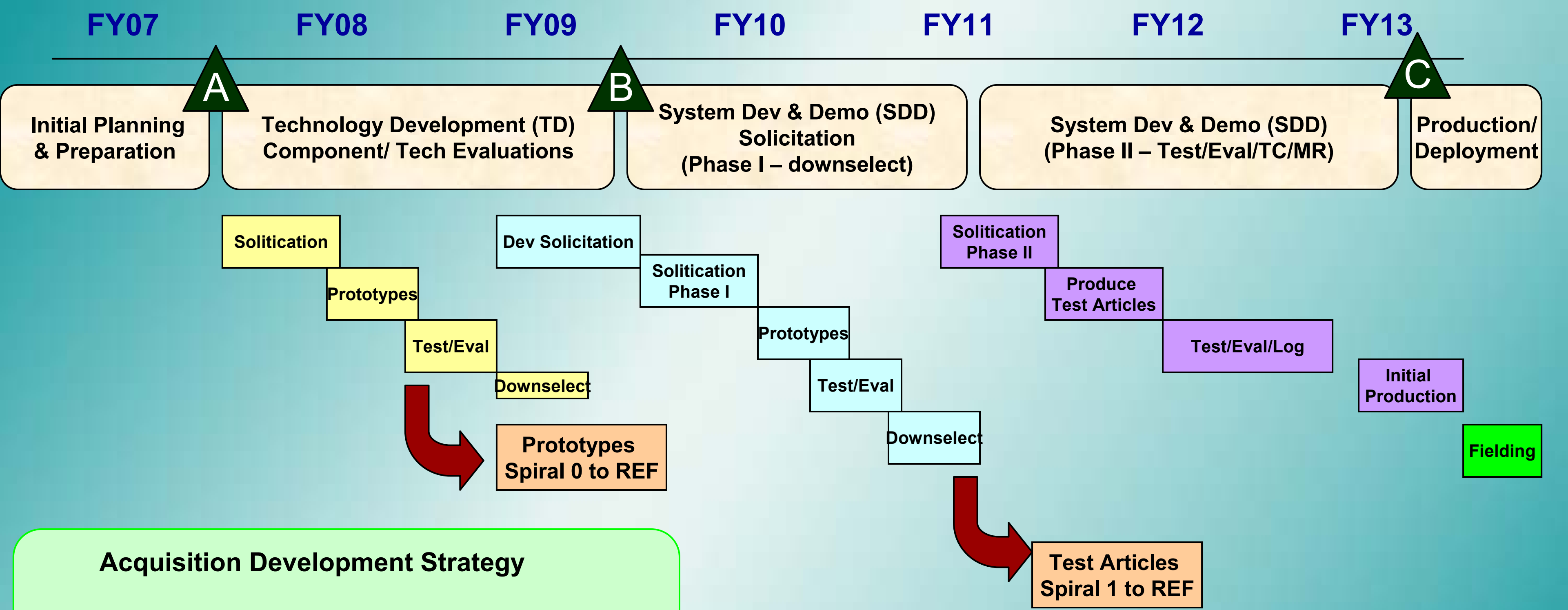
Objectives Of HI-POWER Program

- **Develop tactical transportable hybrid electric power sources**
  - ❖ **To reduce logistics fuel consumption related to power generation**
  - ❖ **To meet niche operational capabilities for remote reliable power**
  - ❖ **Minimizes logistics or operational impacts**

- **Validate HI-POWER concept**
  - ❖ **Evaluate real-world utility (cf, REF SkyBuilt and USMC DREAM)**
  - ❖ **Identify and document requirements for systems (TRADOC)**
  - ❖ **Establish analytical business case (cost-benefit analysis)**

- **Develop strategy that**
  - ❖ **Establishes HI-POWER as Joint Standard Mobile Electric Generating Source (IAW DoDD 4120.11)**
  - ❖ **Supports current military and commercial protocols and standards (esp., MIL STD 1332B)**
  - ❖ **Provides opportunities for near-term spiral insertions for quick-reaction capabilities (if required)**
  - ❖ **Ensures supportable systems within the military logistics system**

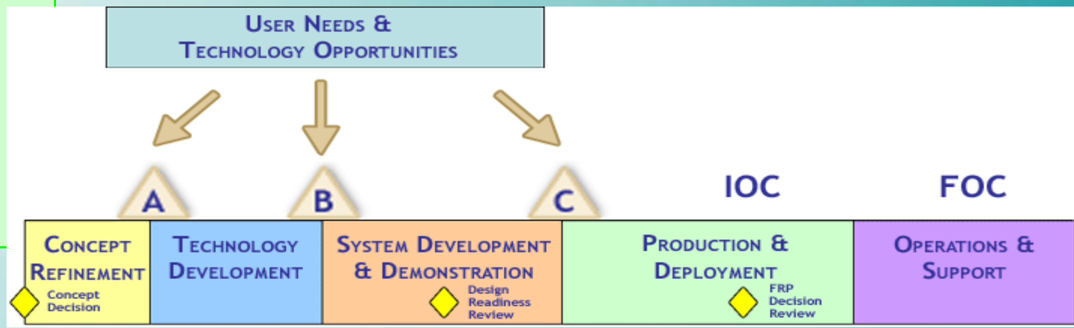
HI-POWER Program Acquisition Summary



Acquisition Development Strategy

- Two step process –technology validation & system development
- Tech Dev to validate technologies and integration strategies
- Competitive shootoff ("fly before buy") strategy in SDD
- Spiral Development to accelerate quick reaction to field
- Ensure standardized, logistically supportable, Joint Service capable systems

DOD Acquisition Lifecycle Model



HI-POWER – Hybrid Electric Intelligent Power Management

Technology Thrusts

Technology Thrusts
Where We Need To Push the Envelope

Easier Deployment

(More per aircraft/ship)

- Less Weight per kW
  - Increased power density
  - Lightweight materials
- Less volume per kW
  - Increased power density
  - Improved packaging/ integration

Easier Sustainment

(Less supplies and manhours needed to operate)

- Less Fuel Consumption
  - Increased efficiency
  - Better load management/power distribution
- More Reliable
  - Fault tolerant design
  - Embedded prognostics/diagnostics
  - Less maintenance hours

Less Life Cycle Cost

- Less Initial Cost
  - Increased use of commercial components
  - Modularity
- Less Fuel Consumption
- More Reliable
- Longer Life
  - Improved reliability
  - Improved efficiency

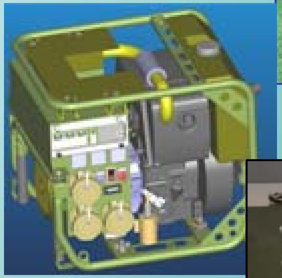
Improved Capability

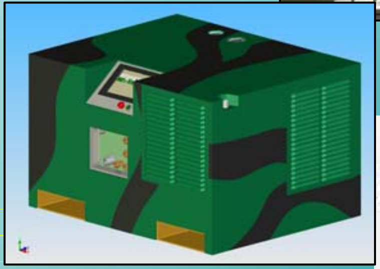
- Less Weight
  - Easier/faster to move
  - Easier to move off road/non-prepared positions
  - More vehicle payload in APU/trailer applications
- Less Noise
  - Use further forward
  - Less communication/rest interference
- Less Fuel Consumption
  - Runs longer on same fuel
  - Fewer fuel trucks doing convoys/fewer soldier manhours spent refueling
- More Reliable
  - Runs longer between shutdowns
  - Prognostics predict impending shutdowns; allows scheduled shutdown versus unexpected shutdown
- Less than 1kW
  - New units to go where power was previously not available
  - Manportable

We are relying on Industry to bring innovation forward.

Potential Technologies

- ***Advanced High Speed Diesel Engines***
- ***Advanced Environmental Control Systems & Combined Power / ECU Systems***
- ***Power Electronics & Digital Controls***
- ***Composite Materials & Lightweight Alloys***
- ***Diagnostic & Prognostic Controls***
- ***Microturbines***
- ***Battery Technology***
- ***Stirling Engines***
- ***Direct Energy Conversion***
  - ***Thermophotovoltaics***
  - ***Fuel Cells***
- ***Tactical Inverters (Vehicle & Shelter)***
- ***Permanent Magnet Alternators***
- ***On-Board Vehicle Power***





Technologies Must Satisfy Operational Needs

DoD Project Manager Mobile Electric Power

Information / Points of Contact

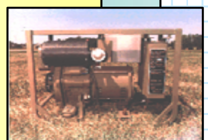
Phones

Project Management Office

DSN: 654-3162

COM: (703) 704-3162

FAX (703) 704-3257



Mailing Address

Project Management Office

Project Manager –
Mobile Electric Power
10205 Burbeck Road
Fort Belvoir, VA 22060-5863

E-mail Addresses

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Acting Project Manager - Mobile Electric Power

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Product Manager (Medium Generator Sets)

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Chief Engineer

Mr. Coady **alan.coady@belvoir.army.mil**
Chief, Logistics Division

www.pm-mep.army.mil

PM-MEP *Home Page*

- **DOD Directive 4120.11**
- **TQG Technical Data**
- **“What’s New”**
- **Safety of Use Messages**
- **Organization and Points of Contact**
- **DOD Generator Master Plan**
- **Manuals, Tools, PLL/ASL**
- **PS Magazine Articles**
- **References**
  (i.e. MIL-STDs, ARs, etc.)

M O R E !

www.pm-mep.army.mil

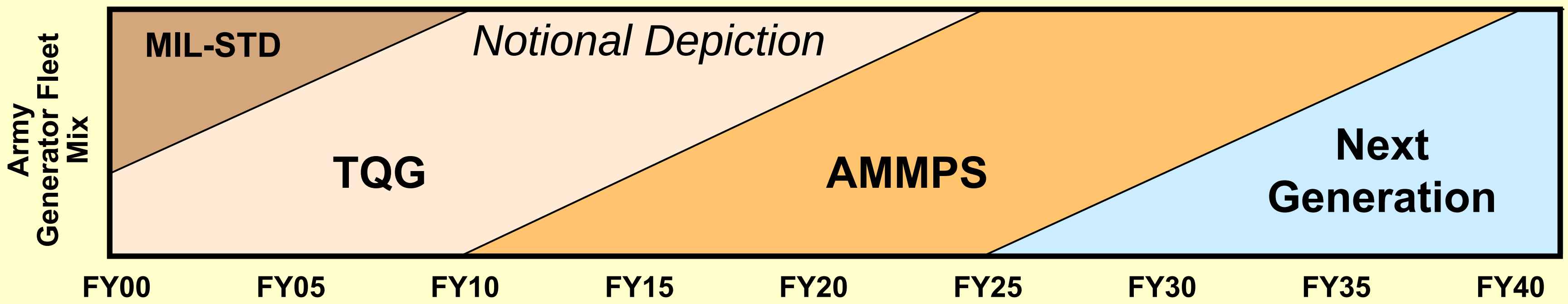
Comments / Recommendations Solicited

Back Up

Joint Service Power Expo

April 2007

Tactical Electric Power
Acquisition Strategy



15 Year Buyout Plan

PROS (Benefits):

- **Maintain hot production base for wartime conditions**
- **Supports Industrial Base by leveling requirements**
- **Maintains Only Two Generations of Hardware in the field at one time**
- **Reduces O&S Costs**
- **Maintains Average Age of Fleet at Economic Useable Life Reducing O&S Costs**
- **Supports Continual Modernization of Army TEP Fleet**

CONS:

- **Keeps Technology in Field for 30 year period**

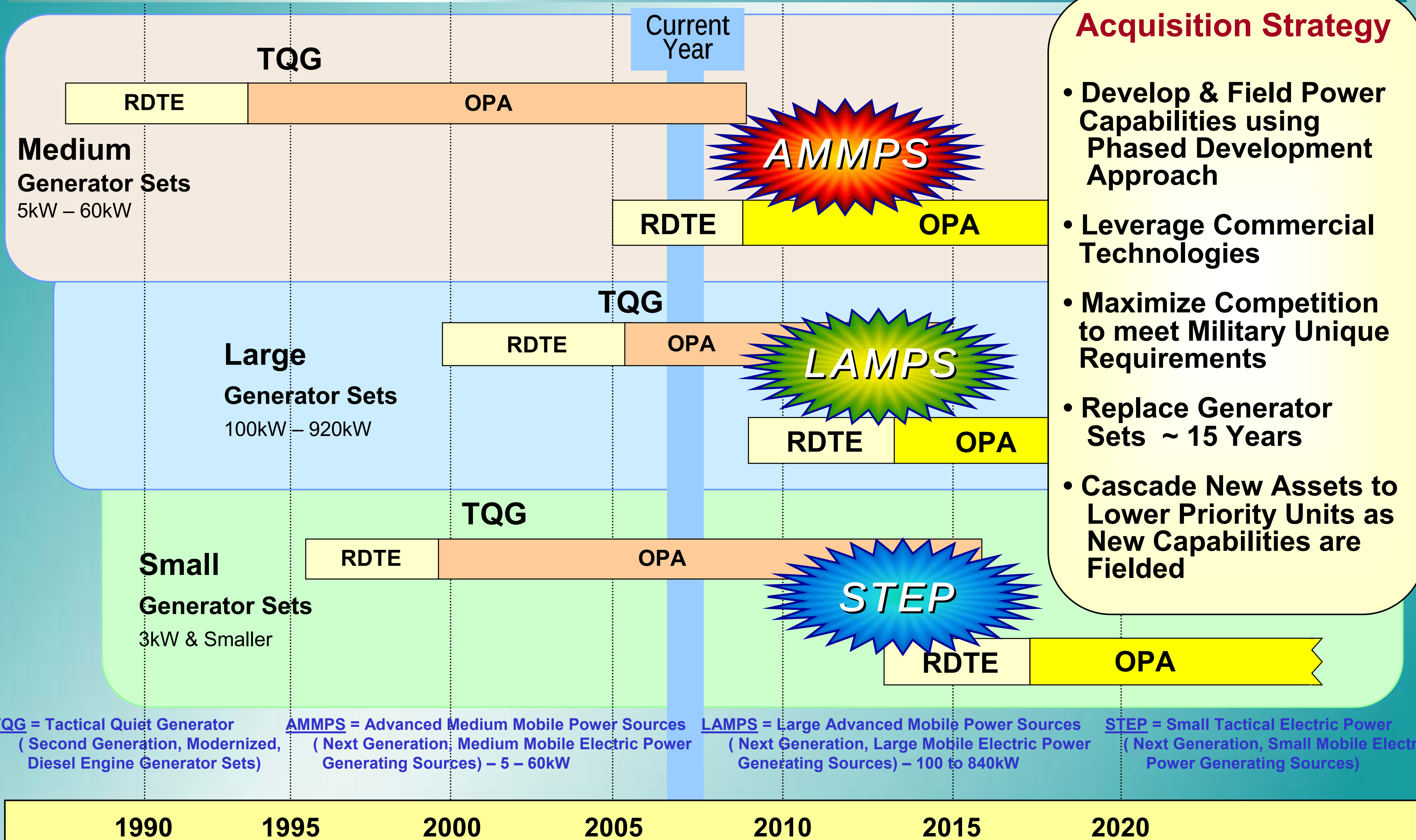
Near Term Business Opportunities

- Distribution Illumination System Electric (DISE)
  - Solicitation Release
    3Q – 4Q FY07

- Switchboxes for
  Power Units / Power Plants
  - Solicitation Release
    1Q FY08

- Improved Environmental Control Units (IECU)
  - 9k, 18k, 36k, BTUH sizes
  - Solicitation Release 1Q FY08

Tactical Electric Power
Development Strategy



Acquisition Strategy

- Develop & Field Power Capabilities using Phased Development Approach
- Leverage Commercial Technologies
- Maximize Competition to meet Military Unique Requirements
- Replace Generator Sets ~ 15 Years
- Cascade New Assets to Lower Priority Units as New Capabilities are Fielded

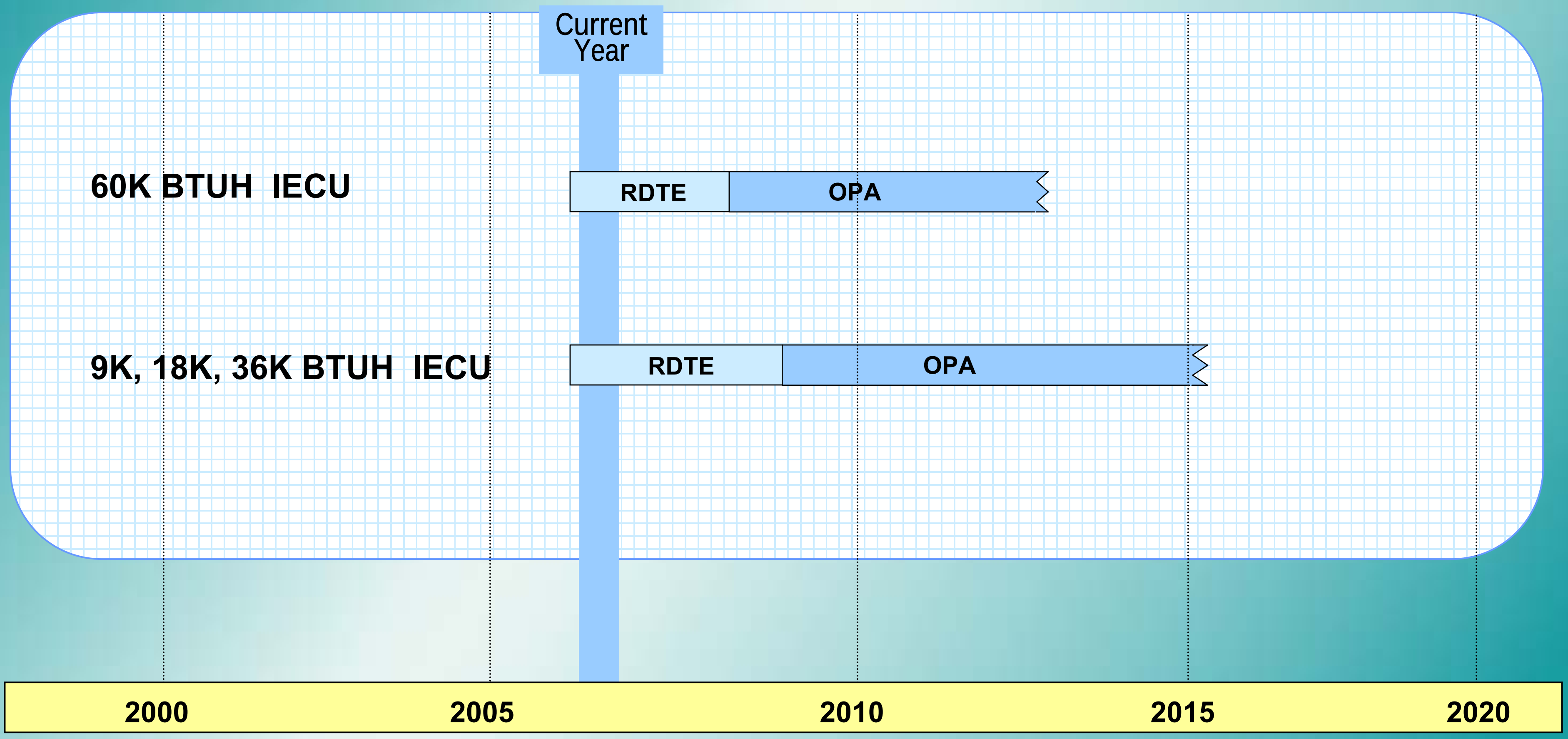
TQG = Tactical Quiet Generator (Second Generation, Modernized, Diesel Engine Generator Sets)

AMMPS = Advanced Medium Mobile Power Sources (Next Generation, Medium Mobile Electric Power Generating Sources) – 5 – 60kW

LAMPS = Large Advanced Mobile Power Sources (Next Generation, Large Mobile Electric Power Generating Sources) – 100 to 840kW

STEP = Small Tactical Electric Power (Next Generation, Small Mobile Electric Power Generating Sources)

Improved Environmental Control Unit (IECU) Development Strategy



Iraq/Afghanistan Lessons Learned

Generator Sets and ECUs

- Power distribution – training/equipment/procedures
- High temperature operation critical
- Sand/dust impacts
- Solar loading (especially on displays)
- Preventive maintenance paramount (but not being done)
- Inadequate parts support – sluggish, but improving
- Requirement for systems assessments
- Military vs. commercial – warfighting vs. base operations

Environmental Impacts & MEP Actions

- **TQG Master Switch –**
  Developed Dust Proof Form, Fit, and Function Replacement Master Switch
- **TQG Computer Interface Module (CIM)**
  Overheating Failures Resolved by Operational Techniques to Reduce Effects of Incoming Solar Radiation (Insolation)

Analog

Digital

CIM

Designed to Operate in All Environmental Conditions

Medium Power Sources
LTC John Kelleher
Product Manager

Description-

5kw, 10kW, 15kW TQG: Primary Power Source on the Battlefield (TOCs, C4ISR, etc.)

CHARACTERISTICS/PERFORMANCE:

Fuel	Diesel/JP-8
Noise	70 dBA @ 7m
Reliability	600 hrs MTBF
Operating Temp	-25⁰ to +120⁰F
Altitude	Full Rating @ 4000ft/95°F

PRIME CONTRACTOR:

5, 10, 15kW: DRS - Fermont, Bridgeport, CT

30 & 60kW: L3, Tulsa, OK

	5kW	10kW	15kW	30kW A/B	60kW A/B
Weight (lbs)	888	1182	2124	3006/3040	4063/4200
Fuel Consumption (gal/hr)	0.56	0.97	1.44	2.43/2.60	4.51/4.70
Size (Cu ft.)	34	41	77	88/88	103/103

ORD - Feb 88

Benefits/Capabilities

- **5 – 60 kW TQG**
- **Multi-Fuel**
- **Reduced Noise and IR Signature Levels**
- **More Reliable**
- **Less Weight**
- **HAEMP Protected**
- **Reduced Fuel Consumption**
- **Total Package Fielding (Organically Supportable)**
- **Power Units/Power Plants**
- **Less Cost (Procurement, Support Cost)**
- **Transportable**

From: Required Operational Capability (ROC)

Requirements Documents

ROC and O&O Plan for the Commercial Generator Sets and Assemblages (CGSA) –
25 February 1988, Revised 10 July 1995

Milestones Achieved/Scheduled

	5,10,15kW and 30 & 60kW A Models	30 & 60kW B Models
Milestone III	**July 1992**	**Aug 2000**
Type Classification	**July 1992**	**Aug 2000**
Production Release	**July 1992**	**Aug 2000**
Materiel Release	**Nov 1993**	**May 2001**
FUE Fort Bragg	**Dec 1993**	
Europe		**Sep 2001**

10 yr Production Contract (FY97 through FY07)

Advanced Medium Mobile Power Sources
AMMPS
LTC John Kelleher – Product Manager

Photo NA

Description-

AMMPS: Future DOD Standard Family of medium (5-60kW) generator sets in 48 different configurations.

Desired CHARACTERISTICS/PERFORMANCE:

TEP ORD Thresholds	TEP ORD Objectives (Compared to TQG)
10% Lighter	25% Lighter
15% More Fuel Efficient	25% More Fuel Efficient
3 dBA Quieter	6 dBA Quieter
20% More Reliable	50% More Reliable
Maint Ratio: 0.025	Maint Ratio: 0.015
EPA Compliant Engines	EPA Compliant Engines

SPECIAL FEATURES MAY INCLUDE:

- Digital Controls, Diagnostics/Prognostics
- Variable Speed Diesel Engines
- Advanced Structural Materials
- Modular Components

KEY CONTRACTORS:

- ONAN Corp./Cummins Power Generation
- DRS - Fermont

Benefits/Capabilities

- **3kW Through 200kW**
- **Multi-Fuel (JP-8, JP-4, JP-5, DF-1, DF-2, DF-A)**
- **Reduced Noise and IR Signature Levels**
- **More Reliable**
- **Less Weight**
- **HAEMP Protected**
- **Reduced Fuel Consumption**
- **Total Package Fielding (Logistically Supportable)**
- **Power Units/Power Plants**
- **Less Cost (Procurement, Support Cost)**
- **Transportable (EAT, 5 & 10 kW Air Drop, etc.)**

Requirements Documents

Title Date	App'd by
Tactical Electric Power Operational Requirements Document (TEP ORD) 24 March 2004	**JROC**

Milestones Achieved/Scheduled

MS B	**1QFY04**
MS C	**3QFY08***
Full Materiel Release	**1QFY09***
FUE	**2QFY09***

***Pending revision based on Phase II/III contract award.**

Large Power Sources

LTC John Kelleher
Product Manager

Description-

100kW & 200kW TQG: Replaces the current 100kW & 200kW MIL-STD gen sets. Available in both skid and trailer mounted. Typical units – Medical, COSCOMs, Hospitals, Homeland Defense.

100kW & 200kW CHARACTERISTICS/PERFORMANCE:

Fuel	Diesel/JP-8
Noise	70 dBA @ 7m
Reliability	840 hrs MTBF
Operating Temp	-25°F to +120°F
Altitude	Rated pwr to 4000ft/95°F

	100kW	200kW
Weight (lbs)	5,800	9,100
Fuel Capacity (gal)	60	120
Fuel Consumption (gal/hr)	7.8	13.9
Size (Cu ft.)	160	250

ORD - CGSA ROC (100kW), Mar 88/Jul 95

PRIME CONTRACTOR: DRS - Fermont, Bridgeport, CT

DPGDS CHARACTERISTICS/PERFORMANCE:

Fuel	Diesel/JP-8
Noise	< 85 dBA
Reliability	TBD
Weight (Wet)	28,560
Size (cu ft)	1,907
Operating Temp	-25°F to +125°F
Altitude	Rated up to 4,000/95°F
Fuel Capacity	120 gal
Fuel Consumption	60 gph
ORD	AFORD (Aug 96)

PRIME CONTRACTORS:

DRS-Fermont, Bridgeport, CT (Contract Ends March 08)
Radian, Inc., Alexandria, VA (Contract Ends March 08)

Benefits/Capabilities

- **100kW, 200 kW and 840 kW (DPGDS)**
- **Multi-Fuel**
- **Reduced Noise and IR Signature Levels**
- **More Reliable**
- **Less Weight**
- **HAEMP Protected**
- **Reduced Fuel Consumption**
- **Total Package Fielding (Logistically Supportable)**
- **Power Units/Power Plants**
- **Less Cost (Procurement, Support Cost)**
- **Transportable**

From: Required Operational Capability (ROC)

Requirements Documents

- **ROC and O&O Plan for the Commercial Generator Sets and Assemblages (CGSA) – 25 February 1988, Revised 10 July 1995**
- **Joint ORD (USAF / USA) CAF-USA 316-92-I/II-E for a NEW FAMILY OF BARE BASE ELECTRONIC POWER GENERATION & DISTRIBUTION SYSTEMS - 29 August 1996, Commander, Air Combat Command**

Milestones Achieved/Scheduled

100kW & 200kW TQG MS C 3QFY04
Materiel Release: Sept '06

DPGDS: USAF-Managed Program. Currently being fielded to 249th Engr. Bn (Prime Power)

Power Units / Power Plants (PU/PP)

Ms. Sidi Mathews

Description

PU/PP: Provide Tactical Quiet Generators (TQG) in trailer-mounted configurations in sizes 3kW, 5kW, 10kW, 15kW, 30kW, and 60kW.

CHARACTERISTICS/PERFORMANCE:

- Power Unit (PU) One Generator Set mounted on one trailer
  - 5kW, 10kW, 15kW, 30kW, and 60kW TQGs mounted on HMT, 1T, or 2½T trailer, towed by HMMWV or 2½T truck (10 separate models)
- Power Plant (PP) Two Generator Sets with switchbox and ancillary equipment mounted on one or two trailers (depending on generator set size and weight)
  - 3kW, 5kW, 10kW, 15kW, 30kW, and 60kW TQGs mounted on HMT, 1T, 1½T, 2½T or 5T trailer, towed by HMMWV, 2½T or 5T truck (11 separate models)

KEY CONTRACTORS / Gov't Activities:

- Schutt Industries, Inc, Clintonville, WI
- Turtle Mountain Manufacturing Co., Belcourt, ND
- Silver Eagle Manufacturing, Portland, OR
- DOL Ft Drum, NY
- DLA Tobyhanna Army Depot, PA
- CECOM Ft Monmouth, NJ & Tobyhanna, PA
- PM-Trailers, Warren, MI

Benefits/Capabilities

- **Provide mobility capability for 3-200kW TQG fleet**
- **Configurations towable behind HMMV, 2 ½ T and 5T trucks**
- **Trailer platforms reliable and supportable**

Requirements Documents

- **ROC and O&O Plan for the Commercial Generator Sets and Assemblages (CGSA) – 25 February 1988, Revised 10 July 1995**
- **ORD for the Less-Than-3kW (LT3kW) Generator – 14 July 1992, Amended 7 March 1996**
- **Tactical Electric Power Operational Requirements Document (TEP ORD) 24 March 2004**

Milestones Achieved/Scheduled

Driven by TQG milestones

Small Power Sources

LtCol Tom Bowers, USMC, Product Manager

2kW MTG

3kW TQG

Description-

2kW MTG: Smallest set in DOD Standard Family. Replaces 1.5kW Gasoline MIL-STD set. Derived from FCT of Canadian design. Very versatile, diesel/JP-8 fueled, man-portable generator set.

CHARACTERISTICS/PERFORMANCE:

Fuel	Diesel/JP-8
Noise	79 dBA
Reliability	500+hrs MTBF
Weight (Wet)	138 lbs DC 158 lbs AC
Size	5.95 cu ft
Operating Temp	-50^0 to $+120^0$F
Altitude	2kW @ 4000ft/120°F derated up to 8000ft
Fuel Capacity	4 hours @ 100% Load
Fuel Consumption	.33gal/hr

ORD -LT3kW 14 Jul 1992

SPECIAL FEATURES:

- Diesel / JP-8 Fuel
- Man-portable
- High Reliability
- Supports MKT modern burner unit (MBU); TUAV / EPLRS / AHS / HIMARS / Woodworking Set / Army Air Traffic System

3kW TQG: Most technically advanced generator set PM-MEP has fielded to date. Replaces gasoline and diesel MIL-STD generator sets.

CHARACTERISTICS/PERFORMANCE:

Fuel	Diesel/JP-8
Noise	70 dBA @ 7m
Reliability	>560 hrs MTBOMF
Weight (Wet)	326 lbs
Size	15.05 cu ft
Operating Temp	-25^0 to $+120^0$F
Altitude	3kW @ 1000ft/107°F de-rated up to 8000ft
Fuel Capacity	8 hours + Auxiliary
Fuel Consumption	.33gal/hr

ORD – CGSA ROC w/Revision 1995

SPECIAL FEATURES:

- Variable Speed Diesel Engine
- Permanent Magnet Alternator
- Digital Controls

Benefits/Capabilities

- **Multi-Fuel (JP-8, JP-4, JP-5, DF-1, DF-2, DF-A)**
- **Reduced Noise and IR Signature Levels**
- **More Reliable**
- **Less Weight**
- **HAEMP Protected**
- **Reduced Fuel Consumption**
- **Total Package Fielding (Logistically Supportable)**
- **Less Cost (Procurement, Support Cost)**
- **Transportable (EAT, 5 & 10 kW Air Drop, etc.)**

Requirements Documents

- **ROC and O&O Plan for the Commercial Generator Sets and Assemblages (CGSA) – 25 February 1988, Revised 10 July 1995**
- **ORD for the Less-Than-3kW (LT3kW) Generator – 14 July 1992, Amended 7 March 1996**

Milestones Achieved/Scheduled

2kW

Re-Buy Production
Award Sep 01
10 Year Contract

3kW

Re-Buy Production
Award Sep 01
10 Year Contract

Power Distribution Illumination System Electrical (PDISE)

LtCol Tom Bowers, USMC, Product Manager

Description

PDISE: A set of man portable power distribution components allowing the distribution of power within a tactical unit. The components consist of four different distribution boxes plus associated cables and a lighting system.

Characteristics/Performance:

Two feeder systems (M200 and M100)
Two distribution systems (M40 and M60)
Utility receptacle and lighting system (M46)
Operating Temp -25°F to +120°F

	M200	M100	M40	M60	M46 Utility Kit
Weight (lbs)	140	77	55	45	85

Future Operational Improvements:

Ability to manage power distribution.
Disconnect low priority loads.
Bring generators on-line as power demands increase.

KEY CONTRACTORS:

- Federal Prison Industries (thru 2013)
- Tobyhanna Army Depot (FY05 contract)

Benefits/Capabilities

Expeditionary Attributes

- Distribute Power
- Ruggedized
- Uses Military Standard Connectors

Quality Power

- Consolidates Power Sources

Requirements Documents

Title	Date	App'd by	Status
Performance Specification For PDISE MIL-REF-53126	**20 April 1992**	**CECOM**	**Requires Update**

Milestones Achieved/Scheduled

FY05 - 06

- **Placed production order with Tobyhanna Army Depot**
- **Completed fielding to 4th ID and SBCT 1-6 to enable TOC Central Power**
- **Completed Power distribution evaluation program (CERDEC)**

FY07

- **Award competitive five year contract**
- **Field to SBCT-7**
- **Field to 101 ABN**

Improved Environmental Control Unit (IECU)

LtCol Tom Bowers, USMC, Product Manager

Description-

The Family of IECUs will provide cooling, heating and dehumidification to soldiers and materiel systems in Combat, Combat Support, and Combat Service Support units. The IECU requirement is derived from the Clean Air Act Amendments of 1990, which bans the use and production of ozone-depleting substances used in existing military standard ECUs by 2030 and bans the production of the current ECUs in 2010. The IECUs have Joint Service applications.

- New generation of ECUs to replace the current Military Standard (MIL STD) family of ECUs.
- IECUs utilize zero ozone depleting refrigerants.
- Form, fit and function replacement to current MIL-STD ECUs.
- Procurement based on performance based requirements vs. technical data package drawings.

Benefits/Capabilities

- Reduced system weight by 10 – 15%
- Reduced power consumption by 25%
- Soft start (i.e. reduced inrush current)
- Increased reliability: MTBF = 2100 vs. 960 hrs
- Increased supportability due to readily available commercial components
- Logistics footprint is greatly reduced by lighter-weight IECUs that require much less electrical power and, consequently, less fuel and potentially downsized generators.
- IECUs utilize zero ozone-depleting refrigerant.
- IECUs are designed for "military environment". Able to survive "military" handling and transportation requirements.
- NBC filtration compatible and EMP/EMI protected
- Operate at wider operating temperatures
- More ruggedized than commercial ECUs.
- Embedded diagnostics.
- Automatic safety controls.
- Remote control capability.

Requirements Documents

Title	Date	App'd by	Status
ORD for IECU CARDS #16123	**Oct 2004**	**Army G-3**	**Approved**

Milestones Achieved/Scheduled

- 60K IECU -

- **Awarded 60k IECU SDD contract – Apr 06**
- **Logistics Demonstration – May 07**
- **PQT Completion – Jul 07**
- **TM Val-Ver; User Evaluation – Aug 07**

- 9/18/36K IECU -

- **Award SDD Contract – Mar 08**

Fighter/EW/Helo/Patrol Arc Fault Circuit Breaker Development

April 2007

Sue Waggoner
Naval Surface Warfare Center
Crane
(812) 854-4103
susan.waggoner@navy.mil

What is the Arcing Fault Problem

Problem Description

Thermal Circuit Breakers are not designed to detect arcing (sputtering) faults for aircraft to prevent electrical fires.

- Arcing faults are the predominate typed of fault on aircraft wiring and do lead to many maintenance actions and possibly fires such as Swissair 111.
- The FAA reports an average of 3 smoke in the aircraft events/day in the civilian aircraft fleet

Navy
Problem Definition

- NALDA average annual incident rate of 127.4 per aircraft type, 38 types of aircraft corresponds to an incident rate of 4841 per year.
- Naval Safety Center documented 30 In-flight Navy aircraft wiring fires which caused mission aborts.
- Existing thermal circuit breakers are not designed to detect arcing faults

Expected Payoffs

- **AFCB protects/provides maintenance information on power wires (15-20% of system wiring)**

  1 to 2 million organizational man-hours per year are spent troubleshooting and repairing aircraft wiring. With respect to power wiring incidents, AFCB technology will

  - reduce maintenance man-hours by 35% (70,000 hours)
  - reduce mission aborts and NMC hours by 35% ($9M/year)

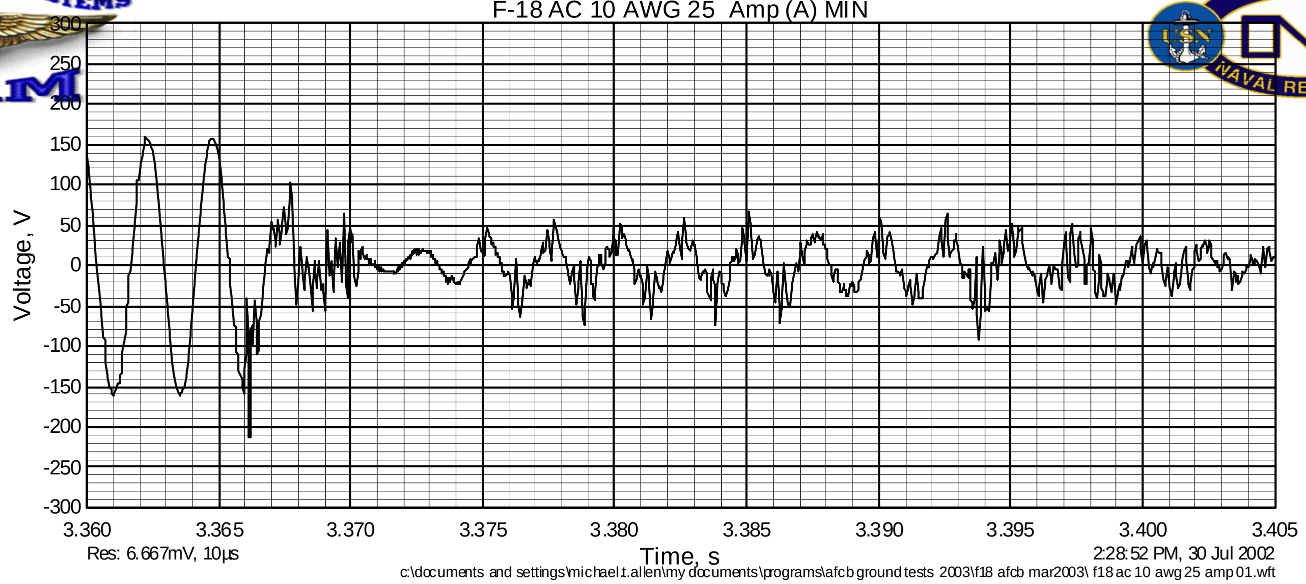
- ***AFCB will protect A/C wiring power system by detecting and isolating arcing fault which can cause smoke in the cockpit mission aborts and fires***

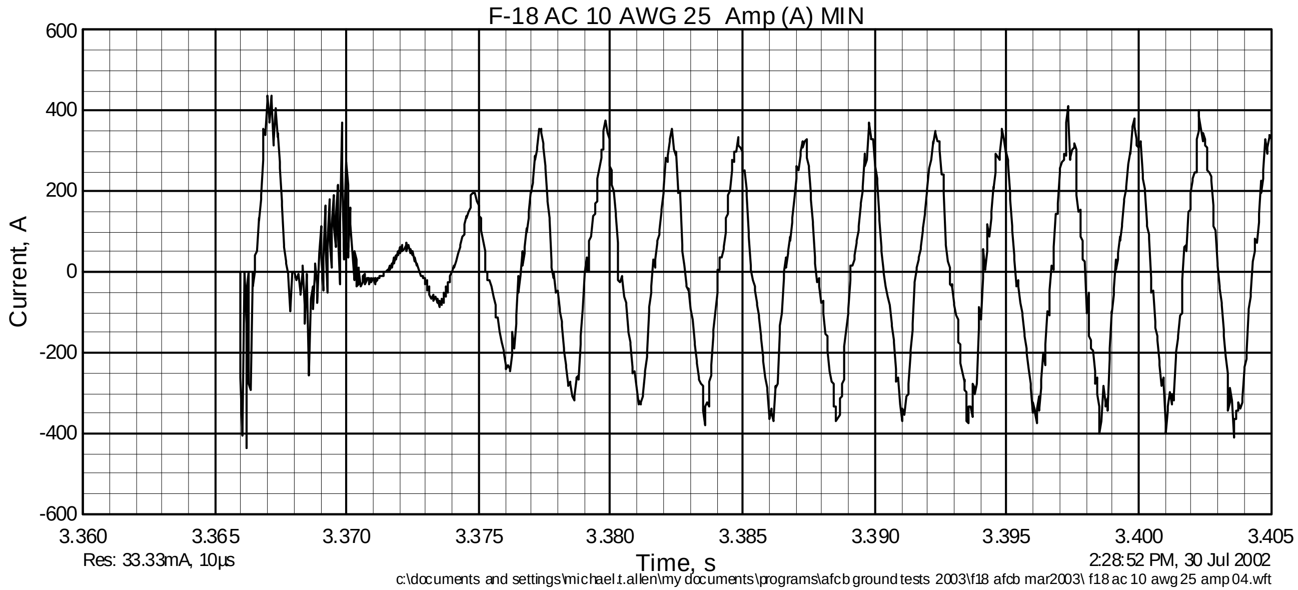
  reduce in-flight electrical fires and subsequent loss of aircraft by 80% ($27.3M/year)

- **Estimated savings of $37.5M per year after full implementation.**

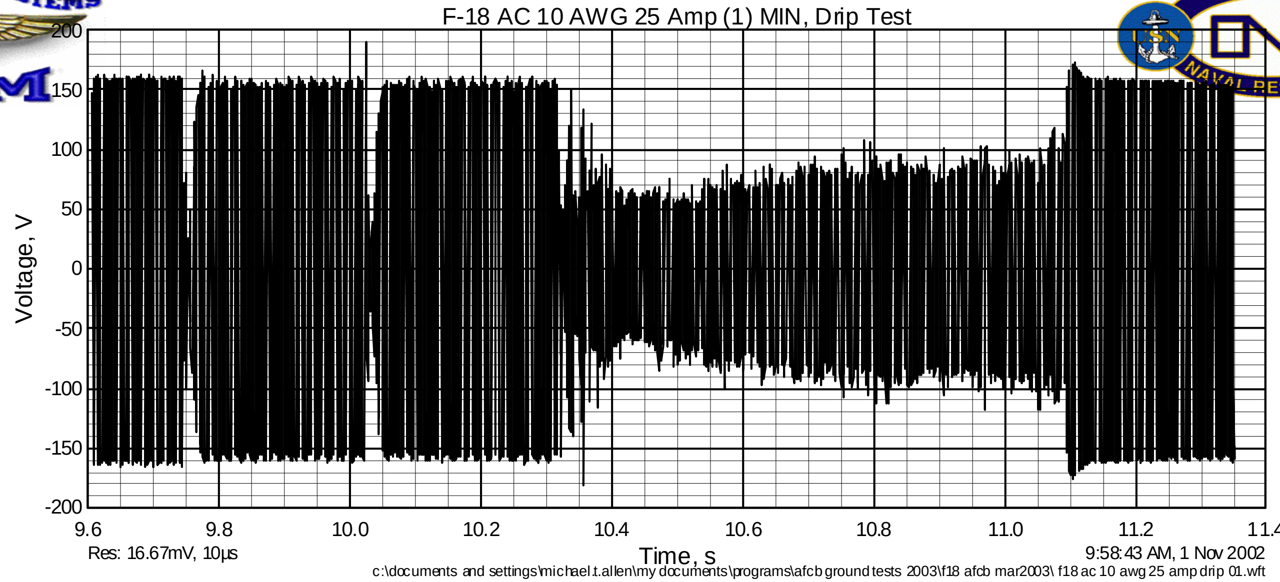
What Does An Arc Fault Current Waveform Look Like?

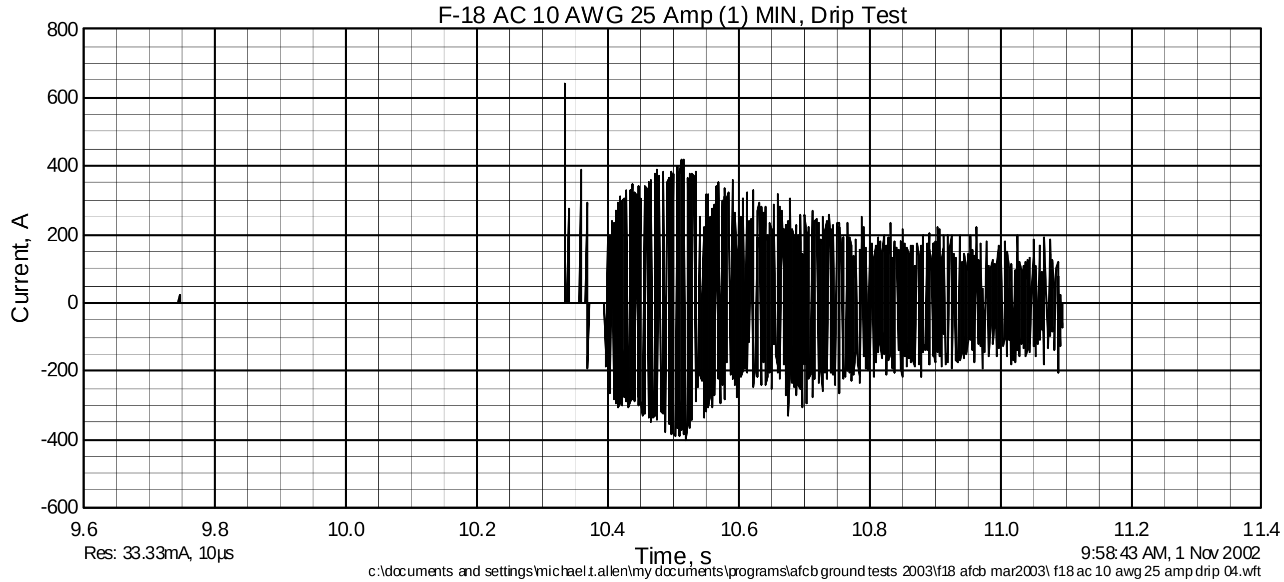
Fixed Wing AC Generator Dry Arc Condition



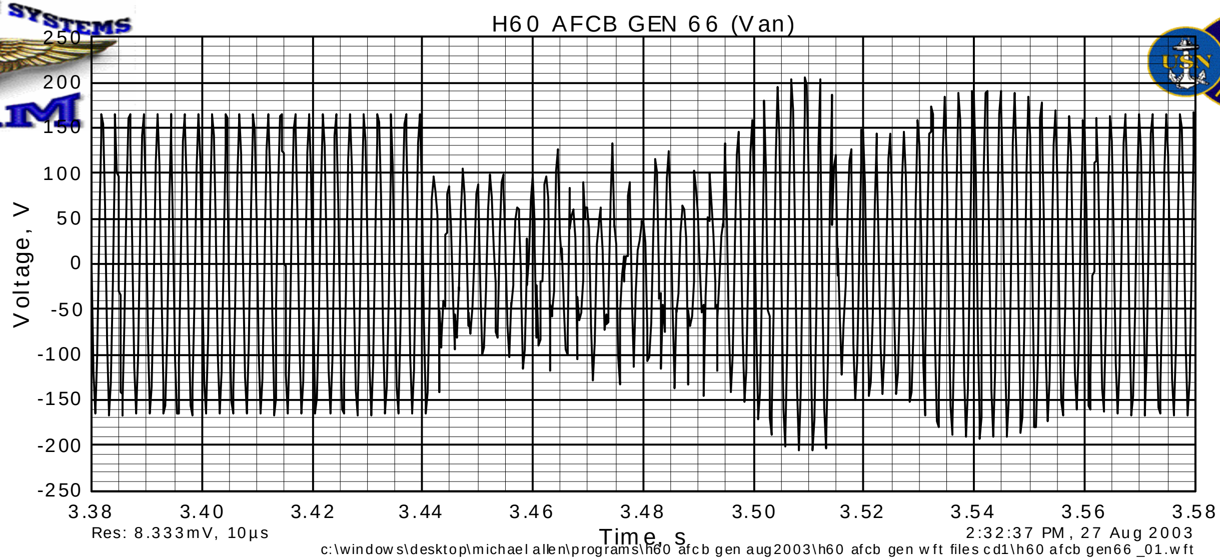


Fixed Wing AC Generator Wet Arc Condition

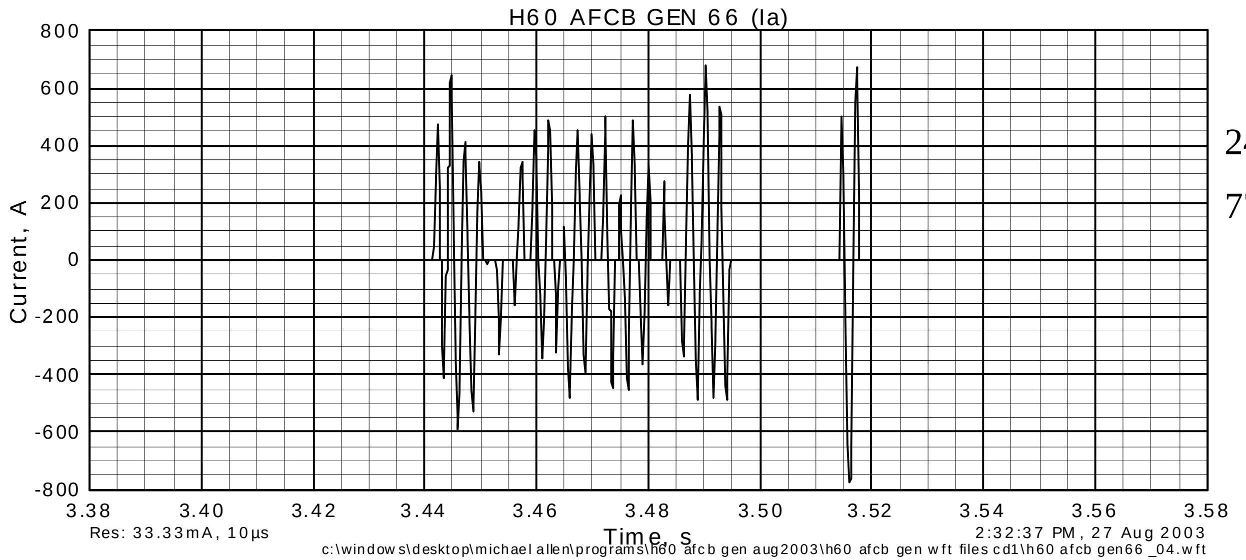




Helo AC Generator Dry Arc Condition



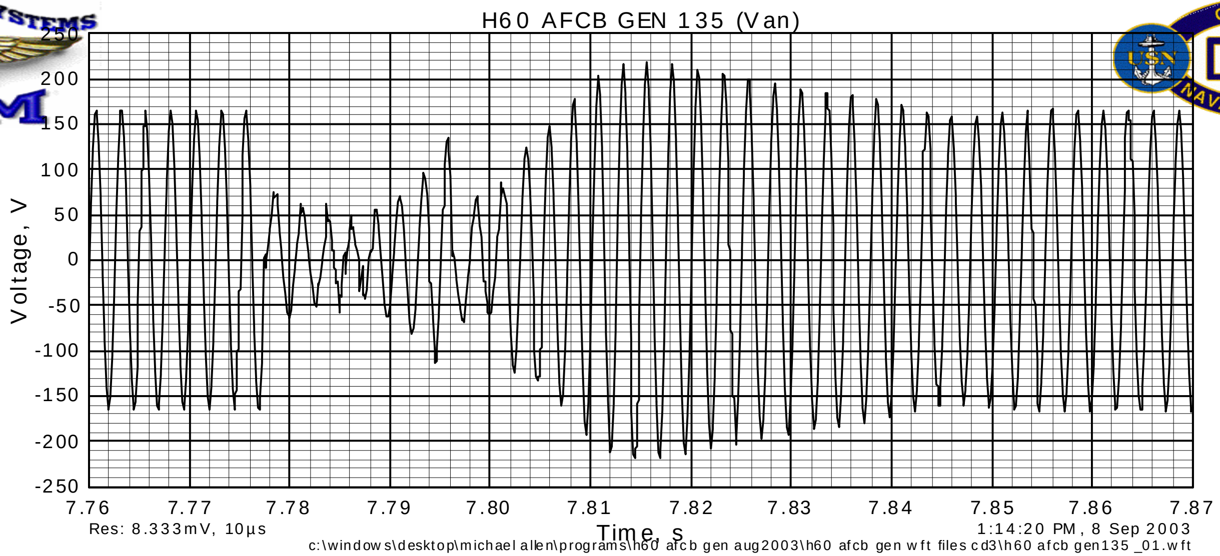
86 Vrms



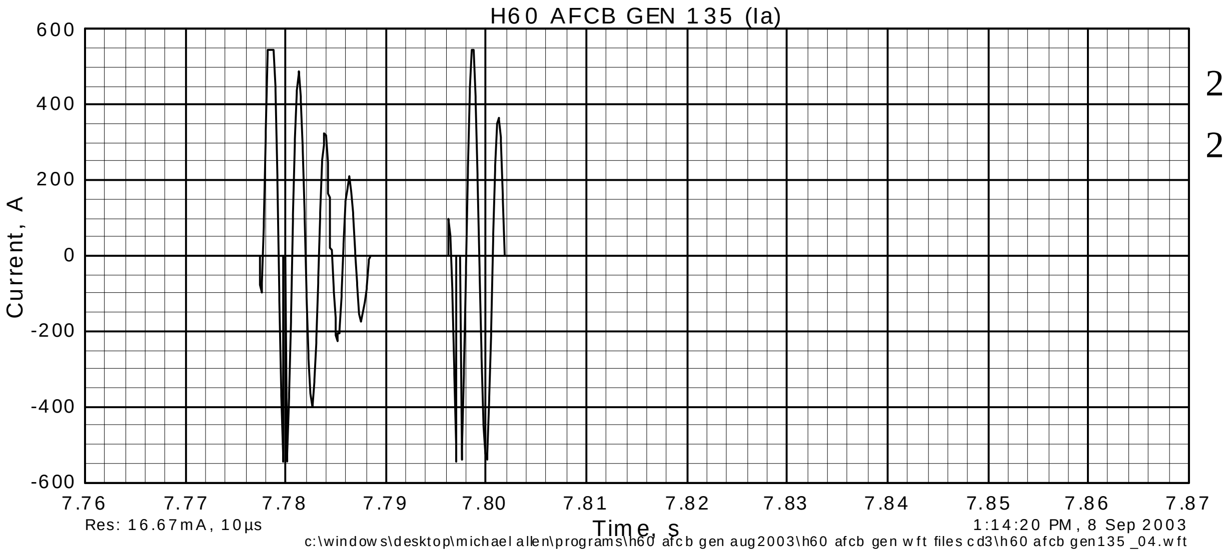
244 Amps RMS Current

77 msec

Helo AC Generator Wet Arc Condition



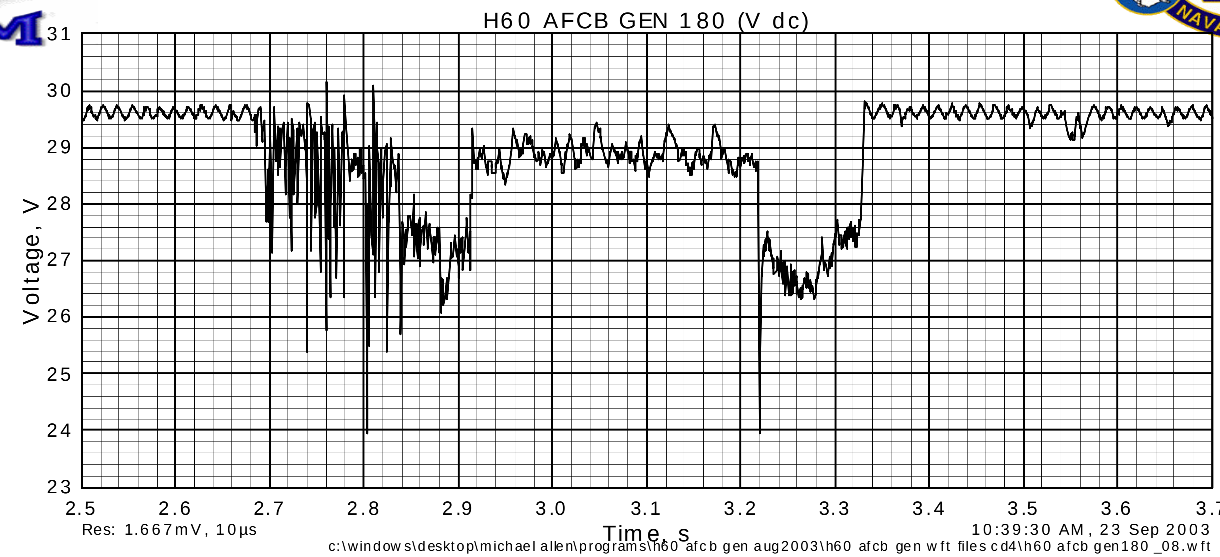
52.3 Vrms



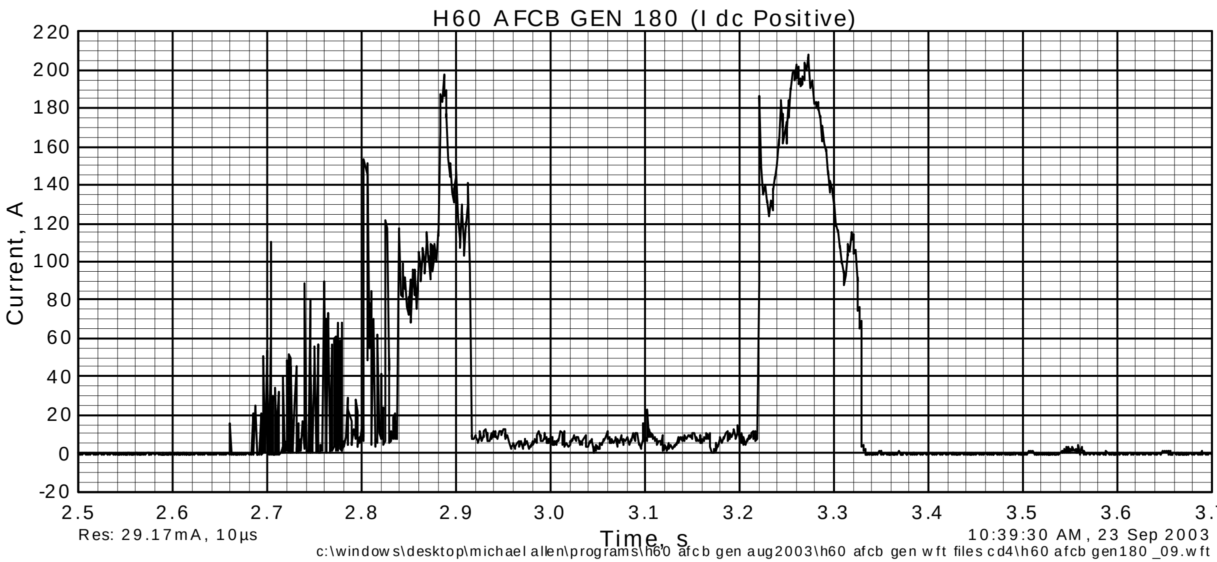
258 Amps RMS Current

25 msec

Helo AC Generator w/ 200 Amp T/R Dry Arc DC Condition



28.24 Vdc Mean

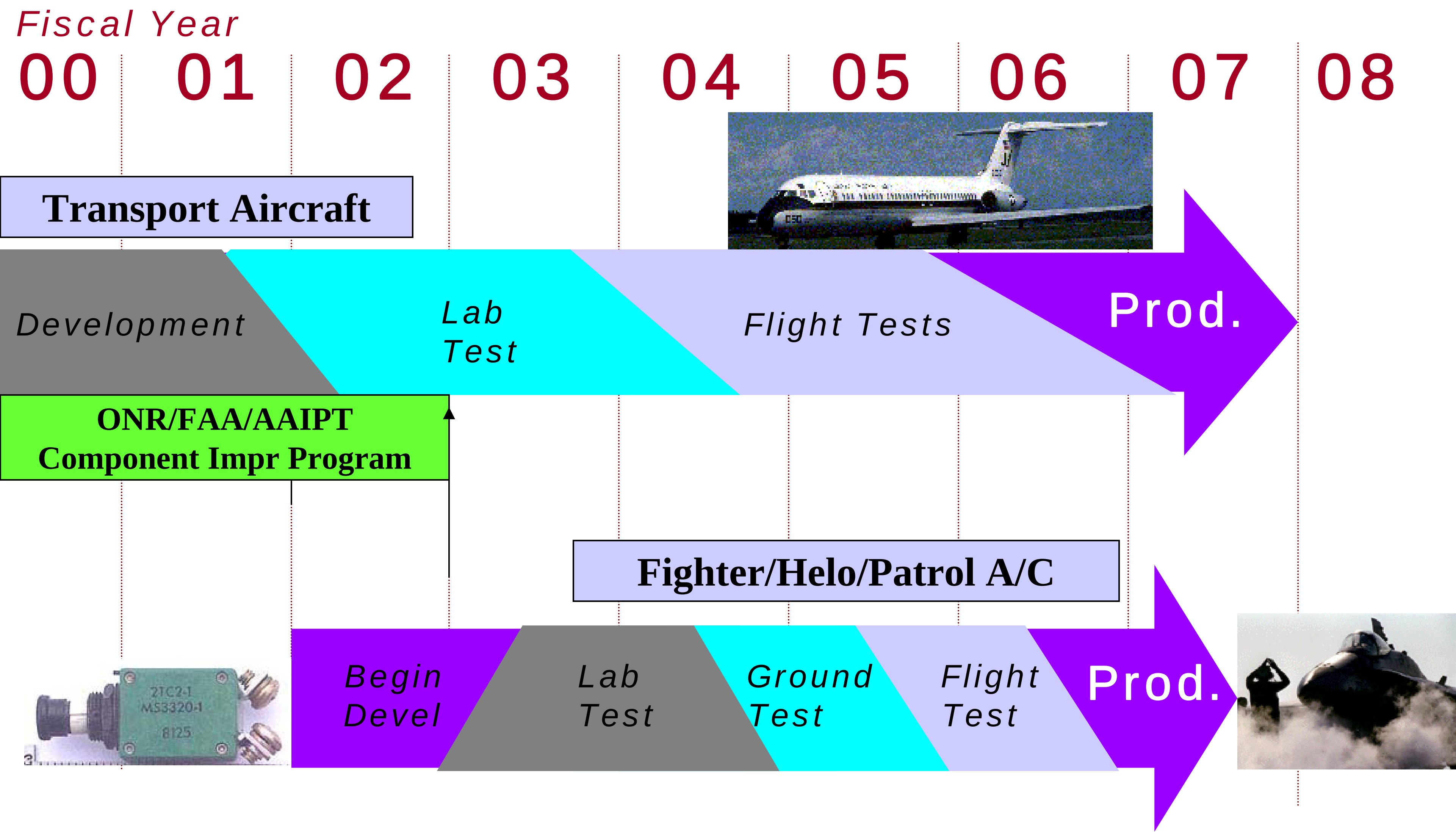


50.07 Amps Mean

What Is Being Developed And Tested?

Arc Fault Circuit Breaker

Developmental Timeline



AFCB - MS14105

- Qualified for Commercial Transportation and Military-Commercial Derivatives
- Originally trying to get from household circuit breaker to a large MS24571 circuit breaker
- Industry fitted arc fault circuitry into a MS14105 and MS3320

AFCB Testing

- Defining Arcing Waveforms
- Defining Electrical Load Waveform
- EMI Testing
- Temperature Altitude Testing
- Vibration Testing
- Electrical Testing
- Flight Testing

Flight Tests

- NAVAIR
  - C-9B 500 Flight Hours – Six AFCB
  - H-53 25 Flight Hours – Six AFCB
  - F/A-18, H-60, P-3 Planned for FY07
- FAA
  - Boeing 727 50 Flight Hours – 20 AFCB
- Industry 10000 Flight Hours
  - Boeing 767
  - Quantus 737

AFCB Transition Plan

- Transition for legacy aircraft through retro-fit on typical 30 month inspection phase
- Transition through retrofit or preferred spare part
- Transition Starts in FY07 depending upon company tooling capability
- Transition Platforms

•H-53	PMA-261
•P-3C	PMA-290
•F/A-18	PMA-265
•H-60	PMA-299

Project Highlights

- Arc Faults have been a constant problem for the past 10 years
- Timeline
  - 6.3 development in FY02
  - ready for transition to E&MD in FY07
- AFCB selected as part of the Core Program under FNC-TOC (6.3 funds)
- Cooperating with Air Force and FAA investigating the problems of arc faults in aging wiring systems with transition opportunities exist within Navy, other Government agencies, and industry

2007 Joint Services Power EXPO
23-27 April 2007
San Diego, CA

Common Sense Approach to the Selection, Design/Fabrication, & Testing of Safe Operational Power Sources

Presented by
Robert Byrnes Sr.
Senior Battery Scientist
DHA Inc

Outline

Common Sense Approach

- Background
  - Bob’s Terms/Advice
- Selection
- Design/Fabrication &
- Testing of Safe Power Sources
- Safety Testing of UltraLast AA Cells

BACKGROUND

MY PHILOSOPHY:

- USE A BATTERY ONLY IF NEEDED
- KISS
- USE COMMON SENSE
- FEEDBACK REQUIRED

EQUIPMENT PROBLEMS

THE CAUSES:

- ANTENNAES
- BATTERIES
- CONNECTORS

BATTERY / PORTABLE EQUIPMENT

AS

BULLET / GUN

BATTERIES
THE “ACHILLES HEEL”
OF
TECHNICAL OPERATIONS

Battery Bob’s Mottos:

“Trust but verify”

Ronald Reagan

“Test everything;
retain what is good.”

1 Thessalonians 5

PREMATURE BATTERY FAILURE CAN:

- CREATE LIFE THREATENING SITUATIONS
- RESTRICT COLLECTION INFORMATION

MOST BATTERY PROBLEMS ARE CAUSED BY PEOPLE WITH:

- **LITTLE OR NO INFORMATION**
- **MISINFORMATION**
- **LACK OF TRAINING/EXPERIENCE**

BATTERY BOB’S

TERMS/ADVICE

THE CAPACITY, ENERGY, POWER RELATIONSHIP

$$E \neq P$$

$$E_{Wh} = \underbrace{V_L (V) \quad x \quad \overbrace{I_L (A) \quad x \quad t\,(h)}^{C\,(Ah)}}_{P_L\,(W)}$$

L - load

THE CAPACITY, ENERGY, POWER RELATIONSHIP SYMBOLS

E = Energy (Work) (Wh)

P = POWER (W)

V = Voltage (V)

C = Capacity (Ah)

I = Current (A)

t = TIME (h)

L = load

AVOID BATTERY PROBLEMS BY:

- Checking Mfgr's Spec Sheet

  Note: No Standard Spec Sheet
- Buying from High Volume Stores
- Knowing Date Codes
- Screening (Primary) OCV & CCV
- Screening & Matching (Secondary)
- Using Common Sense

BATTERY BOB’S AXIOMS:

- THERE IS NO IDEAL CELL!
- ALL COMMERCIAL CELLS ARE ALWAYS UNDER DEVELOPMENT.
- KEEP BATTERY STASHES ROTATED & AVAILABLE TO ALL.
- DON’T MIX BATTERIES w/ BULLETS, COINS, or OTHER METAL ITEMS!

This is what happens if you do.

Name	Size	Chemistry	Temp oC	Temp oF
ECO	AA	Li/SOCl2	113-121	235-250
ECO	AAA	Li/SOCl2	94-106	201-223
Sanyo	CR-2N	Li/MnO2	61-70	142-158
Tadiran	TL-2200 C	Li/SOCl2	88	190
Tadiran	TL-2300 D	Li/SOCl2	70-90	158-194
Blue Star	D	Li/MnO2	50-116	122-241
Panasonic	BR-2/3A	Li/CF	149-151	300-304
Sanyo	HR-AA	Ni/MH	108-115	226-239
Sanyo	HR-4/3A	Ni/MH	73-75	163-167
Duracell	MX-1500 AA	Zn/MnO2	100	212
Sanyo	CR-2	Li/MnO2	76	169
Duracell	DL2/3A	Li/MnO2	91-93	196-199
Duracell	Ultra 123	Li/MnO2	78-93	172-199
Duracell	LM 123A	Li/MnO2	71-84	160-183

SECONDARY BATTERY CHEMISTRIES:

- **Nickel Cadmium-store discharged.**
- **Lead Acid-store charged.**
- **Nickel Metal Hydride-store discharged.**
- **Li-Ion-store 50% charged.**

- **Check out the equipment using the selected cell or battery instead of a DC power supply.**

- **The operation of equipment using a DC power supply may differ from the operation using other power sources.**

- **Where possible simulate the actual use regime as closely as possible.**

SELECTION

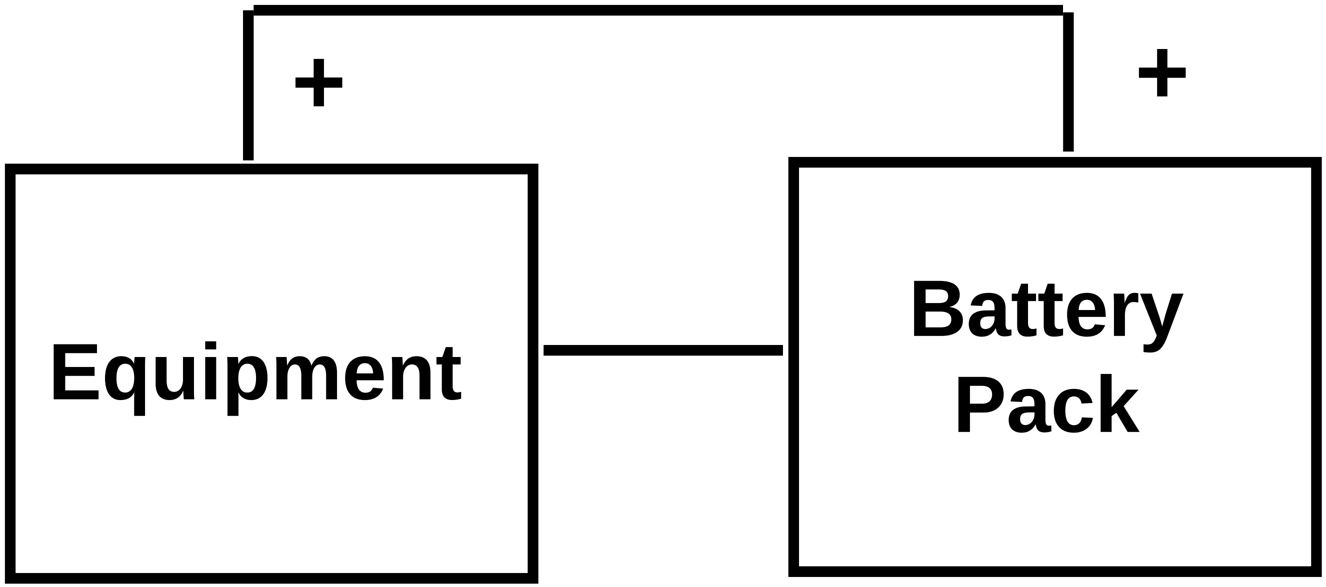
IF YOU WANT A BATTERY FROM ME PICK ONLY TWO BELOW:

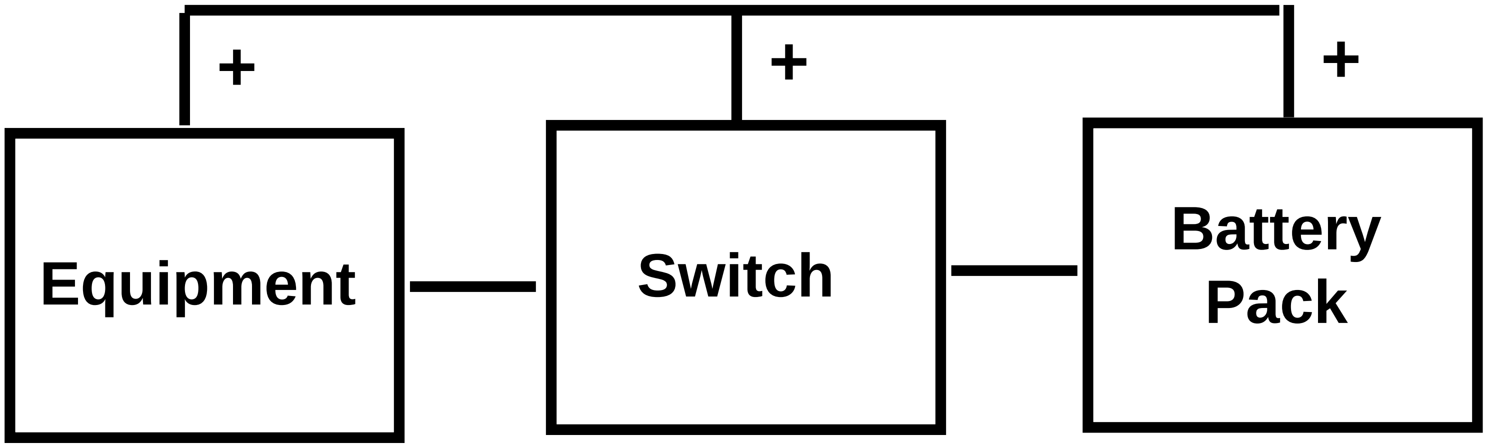
- QUICK
- CHEAP
- SMALL
- RELIABLE

Basic Tips for the User in the Selection of Batteries for Operational Use:

- Define your need as fully as possible.
- There is no ideal power source.
- Don’t make the choice of a power source a last minute decision.
- Keep the power source design simple.

TYPICAL BATTERY PACKS


+
+
Equipment
Battery
Pack


+
+
+
Equipment
Switch
Battery Pack

BATTERY

DESIGN/FABRICATION

CONSIDERATIONS

IF I DESIGN A BATTERY, SHOULD IT BE, A PRIMARY OR A RECHARGEABLE BATTERY?

IF I DESIGN A BATTERY, CAN I FABRICATE IT SAFELY? IN TIME?

IF I DESIGN A BATTERY, CAN I SHIP IT SAFELY? LEGALLY? IN TIME?

FOR LITHIUM BATTERY SHIPMENT QUESTIONS SEE YOUR SHIPPING OFFICER FOR GUIDANCE

WHAT DO I DO WITH THE BATTERY AFTER I HAVE FINISHED WITH IT???

CAN I DISPOSE OF IT SAFELY? LEGALLY?

FOR BATTERY DISPOSAL QUESTIONS SEE YOUR SAFETY OFFICER FOR GUIDANCE

APPLIED BATTERY DESIGN

SIMPLE APPLICATIONS

MAJOR DESIGN CONSIDERATIONS

1) **VOLTAGE**
2) **LOAD CURRENT**
3) **BATTERY LIFE**
4) **SIZE AND WEIGHT**
5) **ENVIRONMENTAL REQUIREMENTS**
6) **SAFETY VENTING**
7) **SAFETY FUSING**
8) **LAYOUT OF PACK TO REDUCE IR LOSSES**
9) **LAYOUT OF PACK TO REDUCE I^2R LOSSES**
10) **DIODE ISOLATION**
11) **CONNECTORS**
12) **LOW VOLTAGE CUTOFF FOR SOME Li CELLS**

MAJOR DESIGN CONSIDERATIONS VOLTAGE

- The devices with which the batteries are used have limitations on the maximum and minimum voltages between which they will work properly.
- The devices may also have limitations on the maximum voltage beyond which they will be permanently damaged.
- There might also be limitations on the minimum voltages below which they will have to be “reset”.
- Does the device perform consistently over the voltage range?
- Is there a preferred voltage?
- Are there multiple voltages required in one pack?

MAJOR DESIGN CONSIDERATIONS
VOLTAGE

- Batteries have maximum, minimum, and typical voltages. How do these match with the device requirements?
- If the battery's operating voltage range does not match the requirements of the device being powered, an electronics package may be needed to regulate the voltage. Otherwise, the full capacity of the battery might not be useable.
- An electronics package might also be needed to control the charging of the battery.

MAJOR DESIGN CONSIDERATIONS
CURRENT

- Affects the life of the battery
- Affects the size of the wiring in the pack and connectors
- Continuous high load current may have a thermal impact
- What is the nature of the current? Is it pulse? Continuous? A mixture of both?

MAJOR DESIGN CONSIDERATIONS
CURRENT

PEAK CURRENT

- The voltage and capacity available from a battery is affected by the discharge current.
- As the current increases, the voltage decreases.
- As the current increases, the amount of capacity that the battery can deliver decreases.
- At some currents, the battery will not produce a usable voltage.

MAJOR DESIGN CONSIDERATIONS
CURRENT

PEAK CURRENT

- EVALUATE PRIMARY vs. SECONDARY
- Primary - good energy density (energy measured in Wh)
- Secondary - good power density (power measured in watts)
- Hybrid - utilize the best characteristics of each *(but with added complications)*

MAJOR DESIGN CONSIDERATIONS
CURRENT

AVERAGE CURRENT

- The number of Ampere-hours that are required is determined by the average current consumed by the device being powered.
- If an average current is not known, it can be calculated from the individual loads, the currents during all operating conditions, and the duty cycle.

MAJOR DESIGN CONSIDERATIONS *LIFE*

How Long Before The Battery Can Fail?

- *Shelf Life*
  - How long must the battery be available before the device operating time starts?
- Operating Life
  - How long must the battery power the device?
- What about End of Life?
  - How Will The Battery Be Shut Down?

MAJOR DESIGN CONSIDERATIONS *LIFE*

SHELF LIFE

- Effects of self discharge on battery life.
- Passivation - high initial pulse need.
- Cell seals - different seals start to leak at different times.
- Storage time before operation.
- Battery maintenance during storage.
  – Some chemistries need to be kept charged lead acid
  – Some chemistries have “memory effects”

MAJOR DESIGN CONSIDERATIONS *LIFE*

OPERATING LIFE

- Effects of discharge current on useable battery capacity.
- Effects of temperature on useable battery capacity.

MAJOR DESIGN CONSIDERATIONS *SIZE & WEIGHT*

CAN THE BATTERY BE CONCEALED?

- Will the weight give it away? *Too heavy or too light?*
- Will the size give it away? *Too big?*
- Will it fit in the electronics package? *Wrong shape?*
- Certain chemistries swell upon discharge.
- If a cell should go bad, is there enough capability left in the other strings to handle the mission?
  - Often a trade-off of size/weight versus redundancy.

MAJOR DESIGN CONSIDERATIONS
ENVIRONMENTAL REQUIREMENTS

- The performance of a battery is affected by the environment in which it will be used.
- Temperature has an impact on the battery.
  - Useable capacity.
  - High power pulses.
  - Function & Survivability
- The performance and battery design can be affected by other factors
  - Will the battery need to be moved?
  - How will it be moved
    - Road vehicle, Aircraft - Passenger/Cargo, Camel, Etc.
- Worldwide use? Indoor use? Outdoor? Tactical? Jungle? Desert? Snow? Salt fog?

MAJOR DESIGN CONSIDERATIONS *THINGS TO PONDER*

- SAFETY VENTING
  - If a cell should vent, a path for the escaping gases needs to be provided
  - How does this impact on the mechanical design of the electronics package?
- SAFETY FUSING
  - Depends on cell chemistry and/or # of cells

MAJOR DESIGN CONSIDERATIONS
PACK LAYOUT TO REDUCE LOSSES

- HEATING LOSSES = I^2R
- VOLTAGE LOSSES = IR
  - Length and size of wiring in the pack
  - Cell interconnects and location
- DIODE ISOLATION
  - Parallel strings of cells need to be diode isolated
  - Voltage drop across diodes
- CONNECTORS
  - Size and type
  - Wire leads?

MAJOR DESIGN CONSIDERATIONS
REFINING THE CHOICES

- Verify cell selection will meet Operational Requirements

- **Electrical**
- **Environment**
- **Size and Weight**
- **Transportation**
- **Delivery Schedule**
- **Redundancy**
- **Reliability**
- **Cost**
- **Safety**
- **Further trade-offs**

MAJOR DESIGN CONSIDERATIONS
CELL SELECTION

NOT ALL CELLS PERFORM THE SAME

- This is true for:
  - Different chemistries
  - Same chemistries, but different manufacturers
  - Same chemistry and manufacturer, but different sizes
  - Same chemistry and manufacturer, but different manufacture date
- Not all cells are equally predictable or reliable in their performance.

PERFORMANCE
RELATIVE TO MODEL

Different versions of cells give different performance characteristics

Even if they are the same chemistry, manufacturer and size

PERFORMANCE
RELATIVE TO MANUFACTURING DATE

Cell manufacturers change the way cells are built. A cell built one year may be different from another year.

There are many reasons:
- **Cost/Profit**
- **Competitive performance**
- **Build-to-build variation**

PERFORMANCE
RELATIVE TO SIZE

Different size cells give different performance characteristics

Even if they are the same chemistry, manufacturer and general construction (i.e. prismatic, bobbin, spiral wound).

PERFORMANCE RELATIVE TO CHEMISTRY

Different chemistry cells give different performance characteristics.

Even if they are the same size, the chemistry has different characteristics associated with it.

There may be construction differences as well. These may be needed by the nature of the chemistry (Different materials in the can, etc.)

PERFORMANCE RELATIVE TO CUT-OFF VOLTAGE

The amount of Capacity that a cell can deliver can be greatly affected by how low a voltage that the cell can be discharged and still do useful work.

This can be affected by both discharge rate and temperature.

Low voltage cutoff a must for some high powered lithium batteries to prevent reversal.

MAJOR DESIGN CONSIDERATIONS
CELL AVAILABILITY

- **Forward Deployed**
- **Warehouse**
- **Contractor Stockpile**
- **Commercial Purchase**
- **Special Purchase**

MAJOR DESIGN CONSIDERATIONS

CELL LEVEL TESTING

- Qualification Testing
- Lot Acceptance
- Screening
- Specialized testing
  - Environmental
  - Mission Profile
  - Safety

MAJOR DESIGN CONSIDERATIONS

BATTERY LEVEL TESTING

- Environmental
- Safety
- Mission Profile
- Qualification
- Screening

BATTERY PROGRAM CHECK LIST

ELECTRICAL REQUIREMENTS

1. Max. No Load Volts: ______________ V
2. Steady-State or No-Pulse Load Data:
   Max Volts: ______________ V
   Min, (CUTOFF) Volts: ______________ V
   Current at Max. Volts: ______________ V
   Current at Min. Volts: ______________ V
3. Pulse Load Data (IF APPLICABLE):
   Duration of Pulse: ______________ msec
   Frequency of Pulses: ______________
   Max. Volts ______________ V
   Min. (CUTOFF) ______________ V
   I @ Max. Volts (PEAK): ______________ mA
   I @ Max. Volts (AVE.): ______________ mA
   I @ Min. Volts (PEAK): ______________ mA
   I @ Min. Volts (AVE.): ______________ mA
4. Duty Cycle: ______________ Hrs On-Off/Week
5. Service:
   Actual On Time (MEDIAN): ______________ h
   Electrical Capacity: ______________ Ah
   Storage Time Prior to Use (MAX.): ______________ h
   Total Unit Life (Max.) ______________ h

PHYSICAL REQUIREMENTS

1. Size if Prismatic:
   Length: ______________ mm/in
   Width: ______________ mm/in
   Height: ______________ mm/in
2. Size if Cylindrical:
   Diameter: ______________ mm/in
   Height: ______________ mm/in
3. If Irregular Size, Specify: ______________
3. Weight: ______________ g/oz
4. Position of terminals (TOP OR SIDE): ______________
5. Submit Drawing (IF APPLICABLE) of Device Housing Cells/Battery Pack. (USE BACK OF SHEET FOR DRAWING.)

ENVIRONMENTAL REQUIREMENTS

(Note: The electrical requirements presume a temperature of 24 °C (75 °F). It is desirable to specify the electrical requirements at the maximum and minimum temperatures expected.)

1. Storage:
   Expected Temp. Range: ______________ °C/°F
   Expected Avg. Temp.: ______________ °C/°F
   Expected Humidity Range: ______________
   Expected Avg. Humidity: ______________
2. Use:
   Max. Temp: ______________ °C/°F
   Min Temp.: ______________ °C/°F
   Expected Temp.: ______________ °C/°F
   Expected Humidity Range: ______________
   Expected Avg. Humidity: ______________
3. Shock and Vibration: ______________
4. Applicable Specifications: ______________
5. Other: ______________

OTHER REQUIREMENTS

1. Reliability: (What Minimum Capacity is Desired at What Confidence Level?)
   ____
2. Battery Disposal: ______________
3. External Signature: ______________
4. Transportation: (Very Important For DOT Regulated Power Sources.) ______________
5. Delivery Schedule (Include Testing): ______________
6. Operation Scenario(s) – (Be As Specific as possible. Use separate sheet for details if necessary. Classify appropriately.) ______________
   ____
   ____

FOR RECHARGEABLE POWER SOURCES ONLY

1. Desired Charge-Discharge Cycles: ______________
2. Depth of Discharge (DOD) ______________ %
3. Minimum Charging Time: ______________ h
4. Normal Charging Time: ______________ h
5. Charging Modes:
   Constant Current: ______________
   Current Trickle: ______________
   Constant potential: ______________
   Constant Potential (FLOATING): ______________
6. Types of Use:
   Frequent: ______________ h/week
   Standby: ______________ h/week
7. Charging Temp Range: ______________ °C/°F
8. Other Charging/Charger Info:
   ____

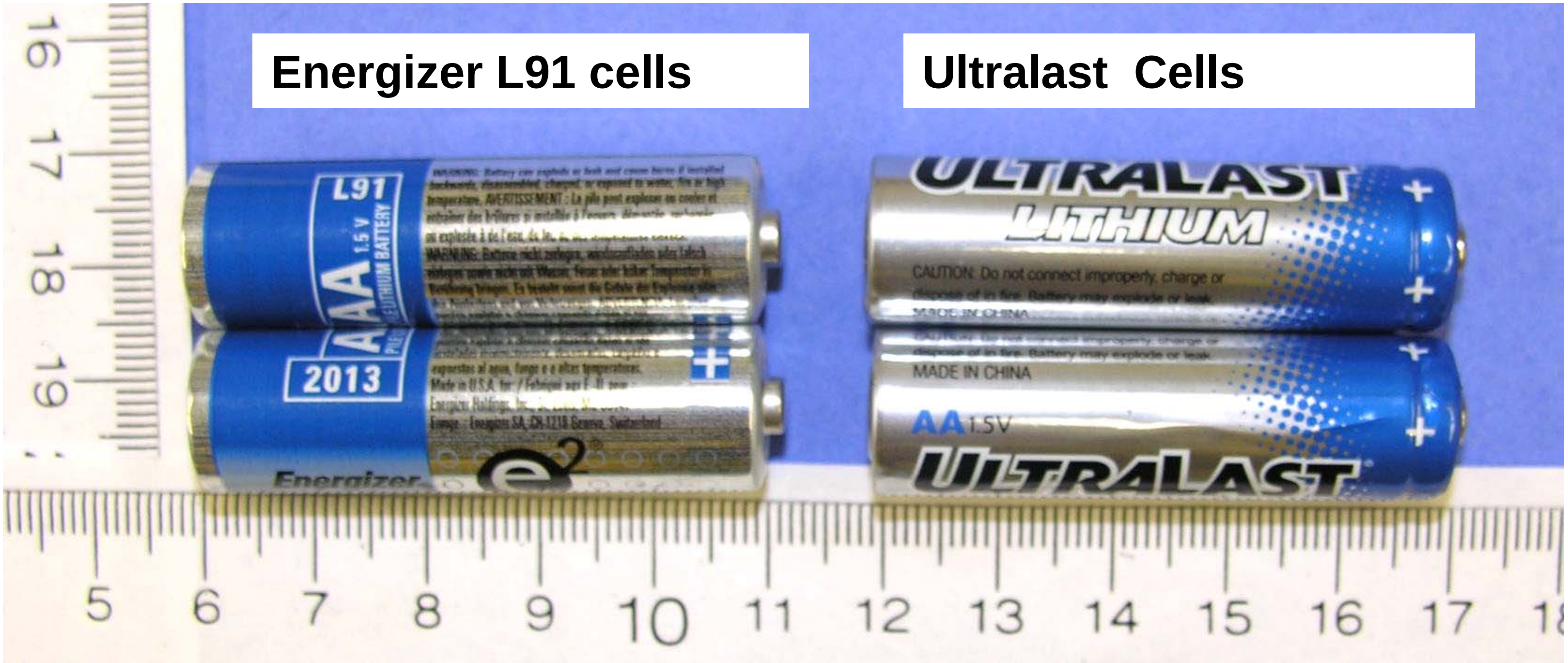
ULTRALAST
Li/FeS2
AA CELLS

Circa early 2006

Background Info

Chinese made AA Lithium Iron Disulfide (Li/FeS2)cells were shipped to the US and sold under the Ultralast label. The Ultralast label was very similar in appearance to the label Energizer uses for its Li/FeS2 AA cell Comparative Safety Testing was done on both the Energizer and Ultralast Li/FeS2 cells.

Introduction



Introduction

UN TESTING of Energizer & Ultralast AA Cells

UN TEST #5: External Short Circuit Test

- Six (6) undischarged Ultralast cells were subjected to a short circuit test of less than 100 milliohms while maintained at 55 °C.
- The output voltage, current, and skin temperature were continuously monitored during the test.
- The short circuit condition was maintained for a minimum period of one (1) hour after the cell skin temperature had returned to 55 °C. The cells were observed for an additional period of six (6) hours.

UN Test #5: External Short Circuit Test Results

- The highest maximum short circuit current was 10.47 amps, while the lowest was 6.54 amps.
- Two cells exhibited fire, with flames emanating from the positive end vent holes, the first cell at 2 hours, 31 minutes, and the second cell at 3 hours, with enough pressure release to pop the oven door open, and temperatures exceeding 170 °C (i.e. 341 °C, and 355 °C). The other four (4) cells oozed a tan colored material from the positive end, and two (2) of them reached 134 C.

Results-Comparison UN Test #5: External Short Circuit Test

- The Energizer L 91 cells, (with 10 cells tested under the same conditions), reached a highest maximum short circuit current of 14.13 amps, while the lowest was 12.57 amps.
- The highest skin temperature reached by any of the cells was 97 °C. None of the cells exhibited fire, rupture, disassembly, or temperature exceeding 170 C.

UN TEST #6: Impact Test
A Lot of Reaction #4 Cell.

Five (5) undischarged Ultralast cells were subjected to the United Nations Impact Test (Test # 6)

The cell under test rested upon a Pine wood “flat surface”, measuring 5 - 1/2 inches X 5 - 1/2 inches X ¾ inch thick. A 5/8 inch diameter hardwood dowel “bar” rested upon the center of the cell, such that the “bar” was perpendicular to the longitudinal axis of the cell and parallel to the “flat surface”. A 20 pound mass was allowed to fall a distance of 24 inches before impacting the “bar”.

UN TEST #6: Impact Test Cont’d.

Upon impact, and for a six (6) hour observation period thereafter, the first three (3) cells demonstrated no evidence of fire, disassembly, or temperature exceeding 170 °C. The highest temperature achieved by any of those cells was 27 °C.

UN TEST #6: Impact Test Cont'd.

The fourth (4th) cell, at 30 seconds after impact, reacted with the ejection of the positive end cap, followed by the violent expulsion of fire and burning material from the positive end (some of which penetrated the aluminum screen), thus, meeting the definition of disassembly. During the period of burning, the cell skin temperature rose to 601 ºC.

The fifth (5th) cell, upon impact, and for a six (6) hour observation period thereafter, reacted the same as the first three cells.

UN TEST #6: Impact Test Cont'd.-Comparison

Previously, the Energizer L91 cell had five (5) cells subjected to the Impact Test.

Upon impact, and for a period of six (6) hours thereafter, there was no evidence of fire, or disassembly, and the maximum case temperature achieved by any of the cells was 95 °C (maximum allowed = 170 °C). Although the end caps were dislodged, they did **not** penetrate the aluminum screen. Therefore, the cells did **not** meet the definition of disassembly.

UN TESTS #5 & #6: Conclusions:

- Ultralast Li/FeS2 cells failed UN Tests #5 & #6.
- Energizer Li/FeS2 cells did not fail UN Tests #5 & #6.
- Cells which do not meet UN Tests should not be imported into the US for sale.
- The Ultralast AA Li/FeS2 cells are no longer being sold in the US but other Chinese AA Li/FeS2 cells are available on the Internet.

Note: 49 CFR 171.12 (a)
Battery Importers

"Each person importing a hazardous material into the US shall provide the shipper and the forwarding agent at the place of entry into the US timely information on the requirements of the regulations that apply to the shipment."

SAFETY TESTING VIDEO of ULTRALAST Li/FeS_2 AA Cells

Contact Information

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BATTERY MAINTENANCE PROCEDURES and CHALLENGES

Presented by:

PulseTech Products Corporation

Mark Abelson

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817-307-5603 (cell)

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www.pulsetech.net

Course Outline:

I. Introduction

II. Conventional battery design

III. AGM battery design

IV. Basic battery facts

V. Common causes of battery failure

VI. Battery Maintenance Procedures

Diagnostics

Corrective maintenance
Preventative maintenance

VIII. Conclusion

WHY IS ANY OF THIS IMPORTANT TO ME?

I. Introduction

What is the GOAL of this training?

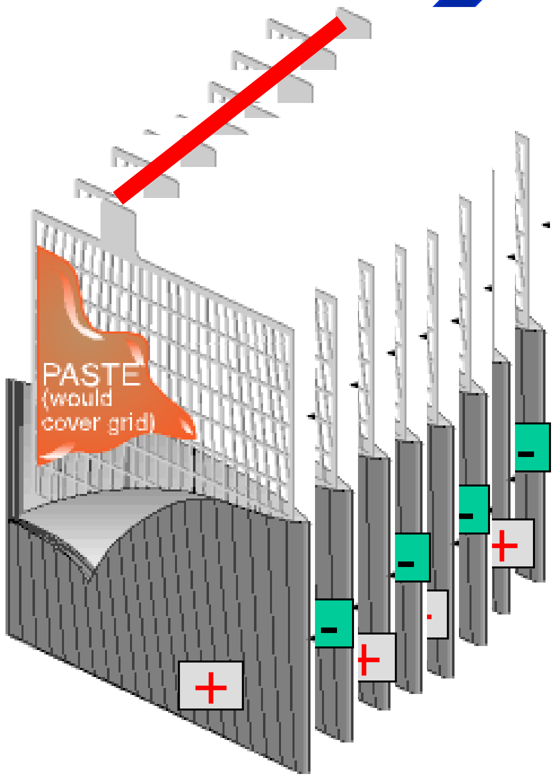
1. Learn methods and procedures to keep batteries in service for over **FIVE** years
2. Improve readiness and save money at the same time

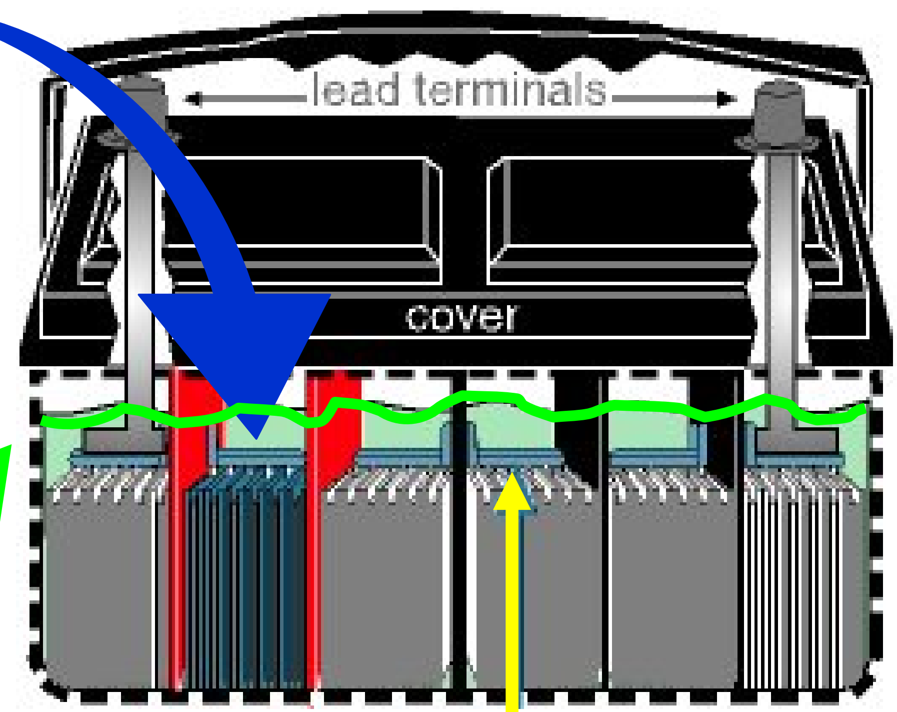
Biggest Challenge:

Change the way to do business with regard to lead acid batteries!

MAINTENANCE FREE
DANGER/POISON
BATTERY, STORAGE, LEAD ACID,
"MAINTENANCE FREE", TYPE I
6TMF
N.S.N. 6140-01-446-9498
12 VOLTS
RESERVE CAPACITY
HIGH DISCHARGE CAPACITY
E-9

II. Conventional battery design





All 6 cells are connected inside the box to make a 12 volt battery

(+) and (-) plates are connected to make a 2 volt cell.

The case is filled with electrolyte (sulfuric acid & water)

Electrolyte must always cover the battery plates **(but don't fill to top).**

Conventional style batteries in use by the US Military:

6TL, 6TLFP, 6TMF, 4HN, 2HN and other commercially available batteries

All of these batteries are flooded ("wet") cell lead acid batteries.
Though they appear similar they have different chemistry, capacities and voltages.

6TMF

The current battery provided by military supply.

Brown case with a black top.

It is also a lead calcium plate chemistry.

Built-in hydrometer (a green eye).

Note: The green eye only allows you to look at one cell in the battery and as such is not a reliable indication of overall battery condition. That is why the "eye" can indicate a battery is good but it still doesn't perform properly.

II. Conventional battery design

Conventional style batteries in use by the US Military:

6TL, 4HN, 2HN

- Use lead antimony plates, many are still in the government system.
- Vary in size and voltage.
- 2HN, 12 volt. Used in small generators, i.e. the 5kW
- 4HN battery is a 24-volt battery (cannot be recovered in current military battery shops due to the lack of a 24-volt charger.

6 TLFP

- This was an interim battery until the 6TMF was fielded.
- Black top and lead calcium chemistry plates.
- Produced and shipped overseas as a dry battery with an acid over-pack.

III. AGM battery design

COMPARISON OF BATTERY SPECIFICATIONS 6TMF LEAD-CALCIUM vs. HAWKER AGM SEALED RECOMBINANT BATTERIES

MILITARY LEAD-CALCIUM BATTERIES

- 12 volts
- CCA – 650
- Reserve Capacity – 200 minutes
- Amp-hours (C/20) – 120
- Usable Reserve – 30% DOD
- Shelf life – 2-3 months
- Type Battery – SLI
- Cycle Life – Unknown
- Life (cradle-grave) –13 months
- Technology – lead-calcium flooded
- Internal resistance – 0.009 ohms
- Resistance to shock – poor
- Transport Class – wet battery (hazardous)
- Environmental designation – "hazardous"
- Weight – 75 pounds (34kg)
- Size (NATO 6T) - 10" (256mm) x 10.5" (269mm) x 8.9"h (227mm)

HAWKER AGM SEALED BATTERIES

- 12 volts
- CCA – 1225
- Reserve Capacity – 240 minutes
- Amp-hours (C/20) – 120
- Usable Reserve – 70% DOD
- Shelf life – 30 months @ 25ºC
- Type Battery – SLI, Deep Cycle
- Cycle Life – 400~ @ 100% DOD
- Life (cradle-grave) – 36/60 months
- Technology – AGM, sealed, recombinant
- Internal resistance – 0.0017 ohms
- Resistance to shock – excellent
- Transport Class – non-spillable, can ship by air or other commercial transport
- Environmental designation – "non-hazardous"
- Weight – 88 pounds (40kg)
- Size (NATO 6T) - 10" (256mm) x 10.5" (269mm) x 8.9"h (227mm)

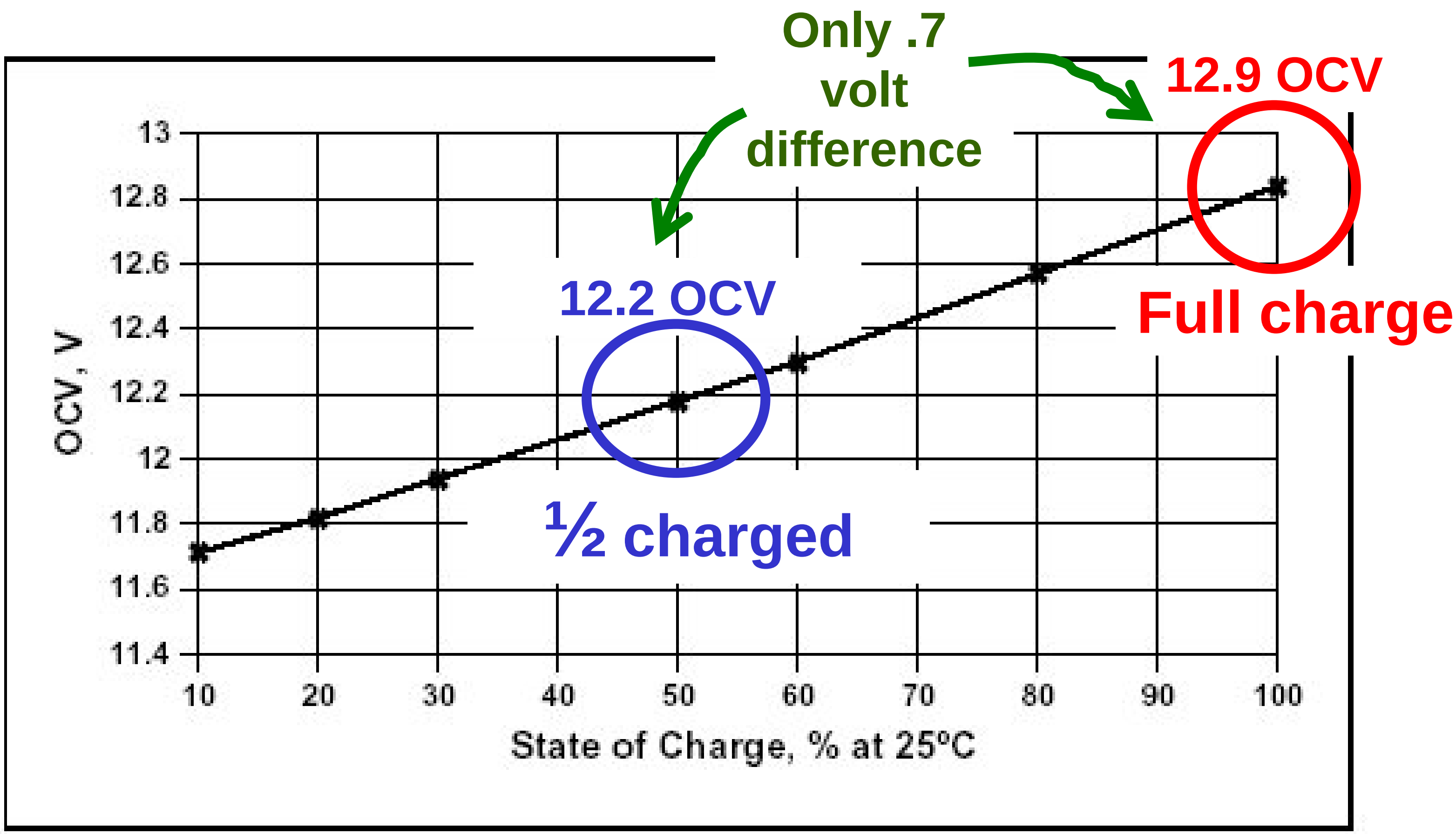
Same basic design as conventional battery, except:

- **AGM batteries use an Absorbent Glass Mat to contain all the electrolyte.**
  - **The AGM holds all the electrolyte like a "super sponge". Battery won't leak or spill even if tipped over or accidentally cracked.**
- **Contains a one way safety valve to prevent out-gassing & loss of liquid during normal operation.**
- **High purity lead (not recycled) plus a little tin**
- **Plates are compressed into cell partition**
  - **Prevents plate to plate movement & shorting**
  - **Prevents loss of active paste material**
  - **Increases vibration resistance.**

Advantages of AGM batteries:

- Longer life
- Less maintenance
- Safer
  - No leaking acid
  - Eliminates corrosion to terminals & battery trays
  - No holes in your clothes, or burning skin
  - Reduced chance of battery explosion
- Battery will work temporarily after cracked open or taking a round.
- Lower internal resistance
  - Higher cranking power
  - More usable reserve capacity
  - Faster recharge

A little voltage means a lot!



Hawker/Optima state of charge versus OCV

All batteries discharge when not being used.

(“self discharge” or “shelf life”)

The rate of self discharge increases as the temperature goes up

For every 10^{o}C rise in temperature

the self discharge rate doubles!

Where are your batteries?

Impact of Congressional Plus Ups and the Vehicle Battery Consignment Program (VBCP)

1. Many of the Hawkers in service today were supplied via dedicated Congressional funding
2. The VBCP is a DLA program that applies to flooded cell batteries (6T; 4HN; 2HN)
   a. One for one replacement
   b. Replacement is NOT FREE
3. The VBCP does not apply to Hawkers
   a. Local DLA may not accept Hawkers
   b. There is no one for one exchange

Common causes of battery failure

Deficit charging:

- **When the vehicle cannot fully charge the battery during normal operation. Results in a decline in capacity (shorter run time of electronics) and reduced battery life.**

Typical causes are:

- **Engine alternator voltage and/or amperage is too low,**
- **Engine run time not long enough to recharge batteries.**
- **High accessory loads (lights, radios, etc)**

Solutions:

- **Install a higher amperage alternator**
- **Shut off accessories when possible (or leave engine running)**
- **Periodically use an external charger to fully charge the batteries**.

Mixing different types of batteries together

Connecting different types of batteries together in the vehicle will lead to shorter battery pack life and possible overcharge or undercharge problems with individual batteries. Premature failure WILL happen.

Solution:

- **Only connect together batteries of identical make and model.**
- **NEVER mix different battery types.**

Leaving (parking vehicle) batteries in a discharged condition:

Even a partial discharge will cause sulfation on the plates that reduces battery capacity and leads to premature battery failure.

Do not leave batteries discharged!

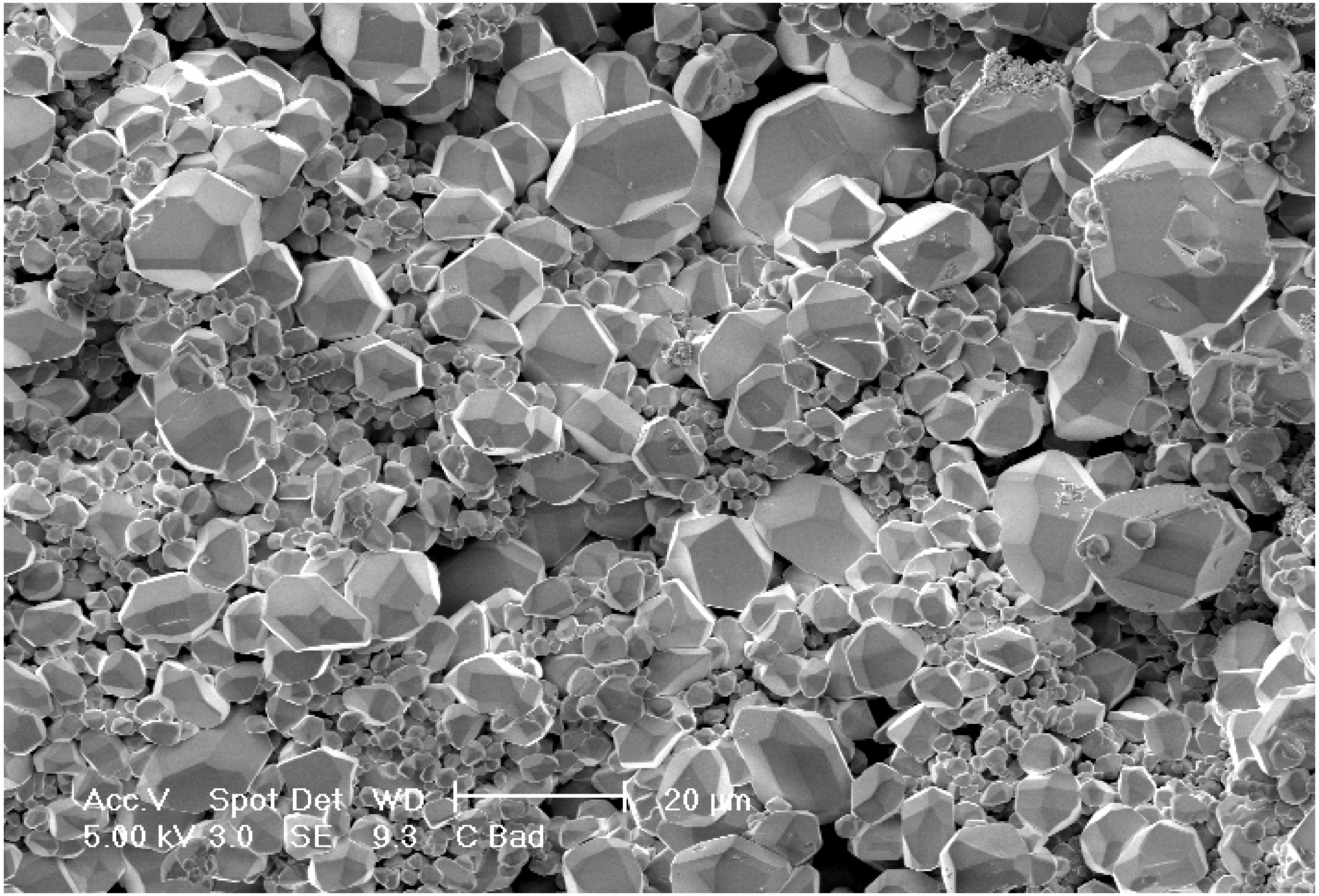
Damage can occur in a very short period.

Solution:

- **Check batteries before storing vehicle & recharge batteries if needed.**
- **If the vehicle or equipment is not used on a regular basis, periodically check the battery OCV and charge when necessary.**
- **Charge whenever the battery OCV is:**
  - **Wet/flooded: 12.5 or less**
  - **AGM: 12.7 or less**
- **When storing vehicles that have on-board electronics use a maintenance charger such as those provided by PulseTech Products to prevent reoccurring battery discharge.**

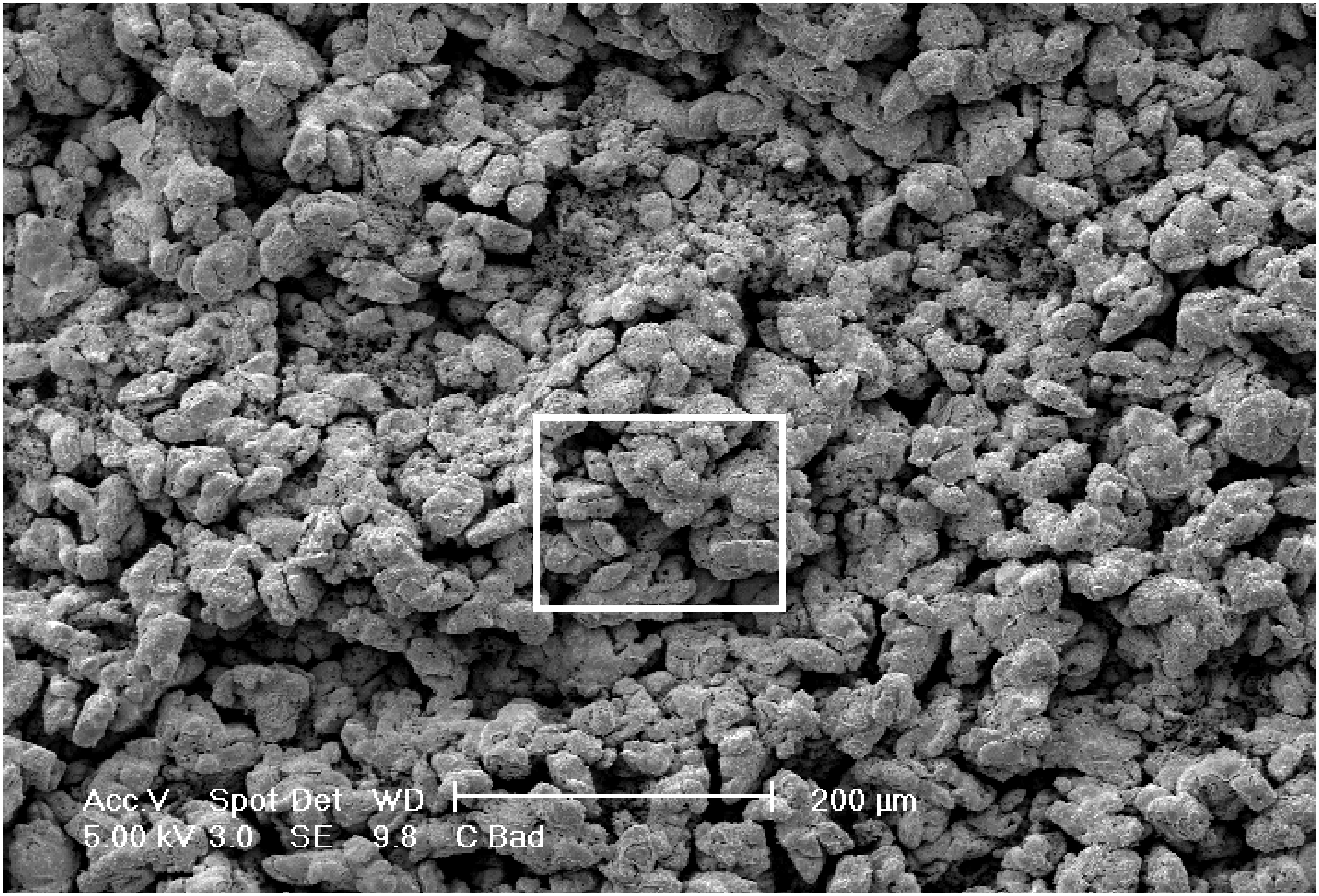
VI. Common causes of battery failure - plate sulfation

Ohio State University
5-year old fully charged batteries



Cathode crystalline structures remaining after charging without pulsing

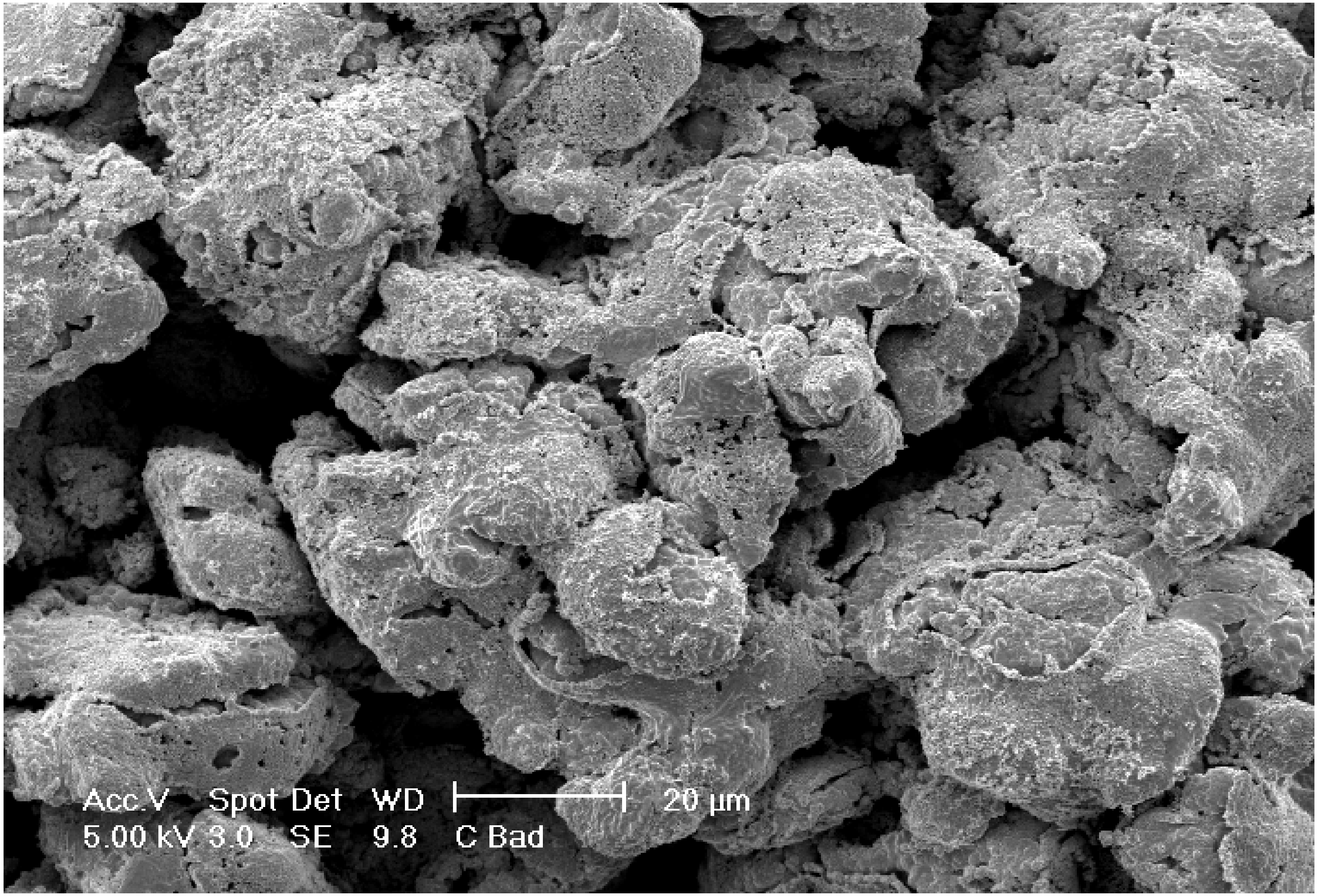
VI. Common causes of battery failure - plate sulfation



Cathode after charging and pulsing with Solargizer.
Area in box is enlarged on next view.

VI. Common causes of battery failure - plate sulfation

Ohio State University
5-year old fully charged batteries



Cathode after charging and pulsing with Solargizer

If the engine starts, the battery must be good, right?

NOT NECESSARILY!

A borderline battery may start the engine, but fail shortly after.

If a battery does not pass the diagnostics tests, it MUST be pulled from the vehicle and sent to the shop for corrective maintenance. If you don't do this, your BMMP will not achieve it's full potential results AND vehicle operation is jeopardized.

Not conducting the diagnostic portion of the BMMP and ensuring your batteries are in good condition as you implement your program is one of the biggest causes for a BMMP to fail.

Diagnostics are an ongoing part of any preventative maintenance program. It will ultimately reduce battery consumption and the money and man-hours expended on corrective maintenance or battery replacement.

Historically the three most common methods of battery testing have been:

- **Multi-meter**
- **Load tester**
- **Specific gravity tester (Duo-check).**

Multi-meter – A good first glance tool to check out a battery.

Voltage and a battery's capability to operate may have little to do with one another. This is especially true with flooded conventional batteries.

An excellent example of this is the occasional battery that won't start a vehicle shortly after being taken off of a battery charger. When the battery is just off charge, a multi-meter will often give you a reading of over 13 volts. Yet when you try to start a vehicle or power radios, it immediately fails and the voltage drops to 12 volts or less. The battery had voltage (surface voltage) but no capacity.

OCV readings alone on flooded batteries are not suitable for determining battery condition or capacity.

OCV readings are more accurate with AGM batteries.

AGM: OCV < 12.7 (25.4 on a 24 volt battery pack) recharge immediately.

Flooded: OCV < 12.5 (25.0 on a 24 volt battery pack) recharge immediately.

Load Testing – One of the most effective ways to test a battery's condition.

A battery shop procedure

Creates a dead short across the battery's terminals with a gauge that indicates how the battery handles the load.

Battery MUST first be fully charged which makes load testing impractical anywhere except in a battery shop.

Load test battery per the equipment's instructions.

If tester is not automatic, set for ½ the battery CCA rating.
(6TMF: 325 amps, Hawker Armasafe: 600 amps)

Discharge for 15 seconds.
To pass the test the battery voltage during load must stay above 9.6 volts

Passing batteries must be recharged again after load test.

Load Testing

Works on both Flooded & AGM batteries

OK for battery shop. Impractical in the field.

Use of Load testers takes time and requires caution.

Enormous heat and mishandling can cause burns.

Tester must be allowed to cool after every couple of batteries.

It is a time-consuming process that presents some genuine training and safety issues to users.

Specific Gravity Testers (Duo-check)

– In the past, Specific Gravity Testers were considered to be the standard for testing military batteries.

Can identify state of charge and bad cells.

Requires that each battery cap must be opened individually and each cell must be tested individually.

Associated safety issues from exposure to battery acid (ruined uniforms, chemical burns, etc.)

Time consuming - opening and closing each cap on a 5-ton truck means that at a minimum, properly testing four truck batteries will take over 30 minutes per truck. At today's manning levels, that is too many man-hours.

(Specific Gravity tests are not applicable to sealed AGM batteries)

So how do you quickly, safely and efficiently test batteries?

CONDUCTANCE TESTING - Excellent snapshot of a battery's condition.

Conductance testing is performed with the **490 PT**. It's easy to use and it can test all four batteries on a truck in about 90 seconds.

The battery does not have to be fully charged, but it does need to be over 5.5 volts.

The 490 PT can be used repeatedly without heating up, opening caps or dealing with sulfuric acid.

CONDUCTANCE TESTING -

Uses an algorithm to compare the battery's available capacity to a known standard.

The PulseTech 490 PT provides the operator with a digital read-out that displays

> Cold Cranking Amps (CCA)
> Whether the battery needs to be recharged and re-tested
> If it has a bad cell
> OCV

Conductance testing is the fastest, most efficient way to test battery condition available at this time.

<u>490 PT and MBT-1</u>

Part Nos. 741x490 and 741x800

(NSNs: 6130-01-510-9594 and 6130-01-463-8499)

Corrective maintenance is intended to reverse or correct a problem that has already occurred.

You found a dead or questionable battery, what's the next step?

The first question that must be asked when batteries are dead is

"<u>Why?</u>"

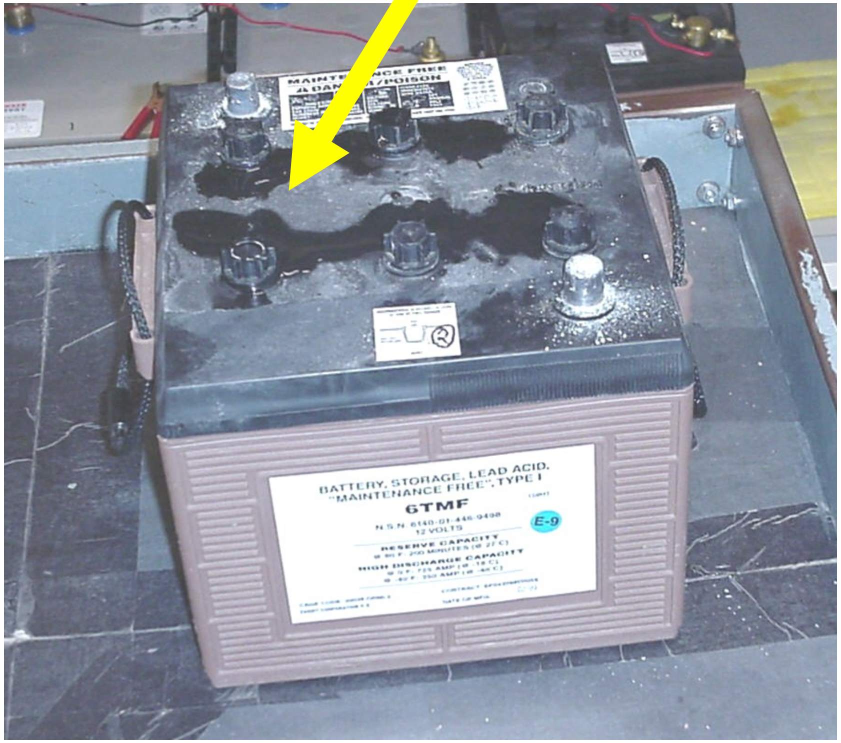
- **Run switch, lights or other electrical devices left on**

- **Short engine run times**
  ("can't refill the bucket" without running the engine longer)

- **Key off loads**
  (loads that are still drawing current from the batteries even with the switch in the off position) newer vehicles have many microprocessors that often add to this problem.

- **Parasitic drain**
  Small shorts in the wires of one or more pieces of equipment on the vehicle. These are generally not large loads or they would trip a fuse or breaker. They pull batteries down over time. These loads must be found and fixed. See Appendix 2 – Parasitic Loads for how to test to see if you have this problem

- **Acid on the outside of the battery case**



Place one probe of a multi-meter (set to DC volts) on either post of a battery and place the other probe on the "non-conductive" plastic case. With a dirty, shiny, or oily top (acid film), you will often see voltage on the meter. That means that the debris on the case has created an electric path and is drawing the battery down. To stop this, the case must be washed with soap and water to remove the oil. Baking soda must also be used to neutralize the acid (DO not allow baking soda to get into the battery cells). They can all be mixed together to make it easier.

Once you have identified and hopefully corrected the cause of the problem -

The dead batteries are sent to the battery shop for testing and attempted recovery.

Battery corrective maintenance must recover batteries to their rated CCA level or they are not worth trying to keep in service!

**If not sufficiently recovered,
replace them with known good batteries!**

Chargers - Must be designed for the specific battery type!

Flooded lead acid batteries use conventional automotive type chargers.

When possible the charger should be an automatic type as to not accidentally overcharge the battery if it's left connected.

AGM batteries need a high quality charger

Voltage needs to be properly controlled

(some automotive chargers can have a very wide voltage swing)

If it does NOT have an AGM or sealed battery setting:

Voltage should be regulated between 14.25 and 14.75 volts.

Recommended amperage ratings of 10 to 40.

All Chargers should be built for rough treatment:

Heavy Duty power supply

Tough clamps for good electrical connection.

Pulse Chargers – The Pulse Charger/World Version PLUS is four products in one.

- 110-volt & 220-volt switch for use within the United States or abroad.
- Switch (on back) for unique requirements of flooded lead-acid batteries and AGM or Gel Cell batteries.
- There is a Pulse Only setting designed to pulse clean the battery internally.
- Pulse & Charge, which simultaneously pulses the battery while it is being charged.

It's also a 20 amp "smart" charger that constantly tests the battery to insure a proper charge. Once the battery is fully charged, the unit switches to Pulse Only to maintain the battery.

(Note: The Pulse Charger incorporates a safety feature that prevents it from starting its charge regimen if a battery is below approximately 6 volts. Batteries below 6 volts can seldom be recovered, however by charging a known mechanically sound battery at low amperage for an hour you can get the Pulse Charger to activate though this is not recommended for safety reasons.)

Pulse Chargers

– The Pro HD is a “smart charger” for use on both 12- and 24-volt systems.

- Fully automatic smart charger senses battery condition and provides only what the battery can accept.
- Charges all conventional lead-acid battery types (flooded cell and AGM).
- Smart technology and pulsing prevents battery gassing and allows charging in the vehicle.
- 40-amp DC output in 12- or 24-volt mode (automatically switches between 12- and 24-volt systems).

Adjusts charge voltage and current to maximize battery recovery and charging. Smart technology and pulsing prevents battery gassing which allows charging with batteries installed in the vehicles.

Pulse Chargers

– The HD Pallet Charger is for use on all 12-volt batteries

- Senses battery condition and provides appropriate charge current per channel.
- Charges all conventional lead-acid battery types (flooded cell, AGM & gel).
- Smart technology and pulsing prevents battery gassing, which allows charging with batteries sitting on the pallet.
- Batteries can be left on pallets and not handled needlessly.
- **Very effective on deeply discharged AGM batteries that have been taken out of service in the past.**
- Charges and conditions up to 12 batteries at a time.
- Batteries no longer need to be separated by type or state-of-charge.

Corrective Maintenance Systems

HD Pallet Charger
Part No. 746x820
NSN: 6130-01-532-7711

Redi-Pulse Pro HD
Part No. 746x800
NSN: 6130-01-500-3401

Pulse Charger/World Version
Part No. 746x725
NSN: 6130-01-398-6951

Redi-Pulse Pro-12
Part No. 746x912
NSN: 6130-01-535-2718

HD Pallet Charger
Part No. 746x820
NSN: 6130-01-532-7711

Redi-Pulse Pro HD
Part No. 746x800
NSN: 6130-01-500-3401

MBT-1
Part No. 741x800
NSN: 6130-01-463-8499

490PT
Part No. 741x490
NSN: 6130-01-510-9594

Redi-Pulse Pro-12
Part No. 746x912
NSN: 6130-01-535-2718

Battery Service Equipment Set (BSES)

- 1 – HD Pallet Charger
- 1 – Redi-Pulse Pro-HD 12/24 volt Charger
- 1 – Redi-Pulse Pro-12
- 10 – MBT-1 Battery Testers
- 1 – 490PT Battery Analyzer

"Initially we didn't think it was going to be anything other than additional charging stations, but immediately we found that we could recover twice as many batteries using the technology incorporated into the BATTCAVE Chargers." DOL – Fort Lewis

Preventative Maintenance

After diagnosis and correction of your battery's condition, the batteries are reinstalled in the vehicles and equipment.

PM also includes checking and charging batteries prior to installation. It is very common to get "new" batteries that have been sitting idle for months prior to your purchasing them. Not starting with a fully charged battery will reduce the battery's life.

Ignored batteries will soon be right back to their start point.

PM is an action to prevent a problem from occurring or reoccurring.

Some PM actions are easy and cost nothing but time, others take more work and have a dollar value assigned to them.

During PM batteries will often be found to be dead or in a low state of charge (this is where the ongoing diagnostic cycle is most evident).

As discussed before, remember the common causes of discharged & failed batteries:

Common causes discussed previously:

- Dirty battery cases
- Parasitic loads
- Key off discharge
- Operator error (lights & switches left on)
- Self Discharge
- Insufficient engine run time

PM equipment:

Solar Charging Systems – Battery maintenance devices used on vehicles to prevent and break up large crystal sulfates on battery plates which occur in discharged batteries.

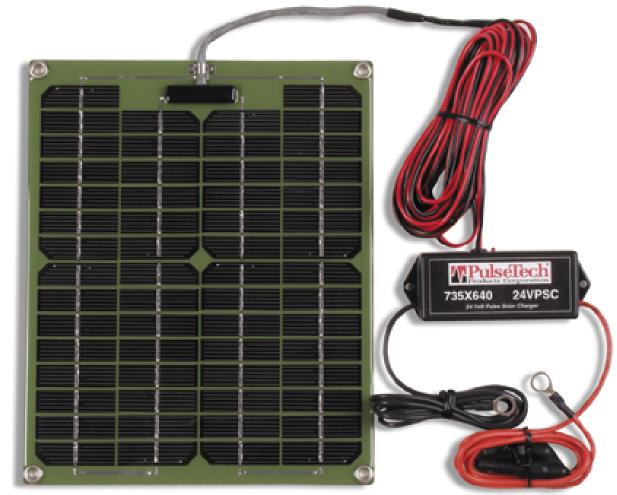
Sulfate crystal formations slowly destroy the battery's capacity.

Solar charge systems can be powered by either sunlight (Solar panel) or an AC receptacle.

Older model solar maintenance systems offset the 6TL's self-discharge from 4.4% to .8% per month.

New solar charge systems maintain and/or charge battery systems.

PM equipment:



24-volt Pulse Charge Monitor System
Part No. 735x643
NSN: 6130-01-497-0964

24-volt Pulse Solar Charger
Part No. 735x640
NSN: 6130-01-487-0035

PM reminders:

- Use of PM equipment described above does not eliminate the requirement of checking electrolyte levels in flooded lead acid batteries.
- PM equipment will not keep dirt and grime off the batteries; they still need to be cleaned.
- Solargizer type products will slow the self-discharge rate of a 6TL, but not overcome it. However, a Solargizer will overcome the self-discharge rate of an AGM battery.

PM reminders:

- Check batteries on a regular basis -
  Whenever doing other PM inspections, or at a minimum every month
  - Battery connections checked and cleaned if needed.
  - Battery hold-down brackets, tighten if battery is loose.
  - Dirty batteries, clean if necessary.
  - Voltage or conductance test. Check and charge or send to battery shop if necessary.
  - Equipment with known battery problems should be checked more frequently until problem is solved.

A properly administered PM program will reduce the requirement for Corrective Maintenance and create huge savings in man-hours and money

Conclusion:

The information and maintenance practices described today will provide direct benefits in terms of:

- **Optimal vehicle electrical system performance**
- **Lower battery related maintenance expenses**
- **Fewer dead vehicles and jump starts**
- **The longest battery life possible**

  - **NEVER DISPOSE OF A HAWKER WITHOUT TESTING AND ATTEMPTING RECOVERY**

Any final questions?

Communications Power Sources and Vehicle Battery Maintenance

Session 7

Joint Service Power Exposition

25 April 2007

Session 7

- Power for Manpacked Radio Communications Equipment

- Mr. Mark Abelson
  - Battery Basic’s for Vehicle Lead Acid Batteries
  - Keeping Batteries in Service
  - 2nd Infantry Division Case Study

Reference Material CD

- BMMP for Lead Acid Batteries
- FY07 Primary & Secondary battery price lists
- POWER 1.2 and Instruction Manual
- Power for Manpacked Radio Systems & QP-1800 (PowerPoint)
- SPC Software Version E
- Zinc-Air battery (PowerPoint)

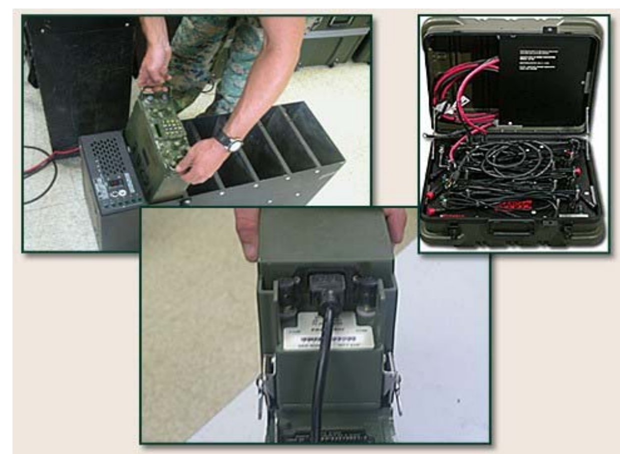
BENEFICIAL SUGGESTIONS

POWER FOR MANPACKED

RADIO COMMUNICATIONS EQUIPMENT

PURPOSE

To review the primary, secondary, and alternative power devices used to energize manpacked radio equipment.



12 VOLT RADIO SYSTEMS

SINCGARS RADIOS

BA-5590B/U	TAB B
BA-5590A/U W/SOCI	TAB B
BA-5390/U	TAB B
BA-5390A/U W/SOCI	TAB B
BA-8140	TAB C
BA-8180	TAB C
BB-390B/U	TAB F
BB-2590/U	TAB F

SINCGARS SINGLE POWER ADAPTER (SSPA) AN/PAC-216 TAB K
MULTI-SINCGARS POWER ADAPTER (MSPA) ASAPS-6 TAB K
MULTI-RADIO POWER ADAPTER (MRPA) ASAPS-SC/SNAP 6CC TAB K

Note: The SSPA will not work with the AN/PRC-119F. The VB-90 (TAB L) is designed for the AN/PRC-119F (ASIP).

AN/PRC-148 (MBITR)

POWER SOURCES

MBITR Battery	TAB L
BA-8140/U	TAB C
BA-8180/U	TAB C
MRC-41	TAB L
Battery Cell Holder	TAB L

The MBITR battery is a unique rechargeable battery manufactured by Thales Inc. When initially fielded the only battery charger to support the MBITR battery was the Thales AC/DC commercial charger. Adapters have been developed to allow use of the SPC and VMC chargers (TAB I) to charge the MBITR battery.

MBITR Battery

Thales AC/DC Charger

24 VOLT RADIO SYSTEMS

AN/PRC-117F, AN/PSC-5, AN/PRC-113 and AN/PRC-150

POWER SOURCES

BA-5590B/U	TAB B
BA-5590A/U W/SOCI	TAB B
BA-8180/U	TAB C
BB-390B/U	TAB F
BB-2590/U	TAB F
MRC-93 Single Radio Power Adapter	TAB K

BA-8180/U with J-6687/U 24V radio adapter (TAB C)

REMARKS

Although the MRC-93 will operate from AC or DC power, the QP-1800 (TAB M) can be used to convert VEH DC power to AC power and energize the MRC-93.

QP-1800

The BA-5390 has not been approved for use in any 24V radio system (refer to TAB B).

PRIMARY BATTERIES (ONE TIME USE)

NEW TYPE	NEW NSN	U/I	FY07 PRICE	OLD TYPE	OLD NSN	OLD U/I
BA-5093/U	6135-01-216-9771	EA	$111.42	N/A	N/A	N/A
BA-5372/U	6135-01-214-6441	PG (10ea)	$91.05	BA-1372	6135-00-801-3493	PG
BA-5112A/U	6135-01-439-6229	PG (4ea)	$196.43	BA-5112	6135-01-235-4168	EA
BA-5557A/U	6135-01-448-4680	PG (4ea)	$370.35	BA-5557	6135-01-088-2707	EA
BA-5567A/U	6135-01-447-5082	PG (12ea)	$63.53	BA-5567	6135-01-090-5365	PG
BA-5567A/U	6135-01-447-5082	PG (12ea)	$63.53	BA-1567	6135-00-485-7402	EA
BA-5588A/U	6135-01-447-5083	PG (5ea)	$198.35	BA-5588	6135-01-088-2708	EA
BA-5590B/U	6135-01-438-9450	PG (4ea)	$293.15	BA-5590	6135-01-036-3495	EA
BA-5590A/U	6135-01-523-3037	PG (4ea)	$348.08	N/A	N/A WITH SOC LED	N/A
BA-5390/U	6135-01-501-0833	PG (4ea)	$446.03	N/A	N/A	N/A
BA-5390A/U	6135-01-517-6060	PG (4ea)	$480.27	N/A	N/A WITH SOC LED	N/A
BA-5598A/U	6135-01-447-5081	PG (4ea)	$176.40	BA-5598	6135-01-034-2239	EA
BA-5599A/U	6135-01-447-4001	PG (4ea)	$163.27	BA-5599	6135-01-069-8575	EA
BA-5600A/U	6135-01-441-0402	PG (8ea)	$286.57	BA-5600	6135-01-168-2944	EA
BA-5800A	6135-01-440-7774	PG (8ea)	$182.25	BA-5800	6665-99-760-9742	EA
BA-5347/U	6135-01-455-7946	EA	$45.07	BA-5347	N/A	N/A
BA-5368/U	6135-01-455-7947	PG (10ea)	$294.65	BA-1568	6135-00-838-0706	EA
BA-5374/U	6135-01-455-9646	PG (10ea)	$131.30	BA-1574	6135-00-073-8939	EA
BA-8140/U	6135-01-517-0952	EA	$275.00	N/A	REQ ADAPTERS	N/A
BA-8180/U	6135-01-500-0572	EA	$355.58	N/A	REQ ADAPTERS	N/A

WARNING – ensure personnel are using the correct NSN's and units of issue.
Many units of issue changed from EA (1) to PG (4), (5), (8), (10) or (12).

TAB A

PRIMARY BATTERIES (ONE TIME USE)

The most widely used primary battery is the BA-5590B/U Lithium Sulfur Dioxide battery. An alternative to the BA-5590B/U is the BA-5390/U Lithium Manganese battery. The BA-5390/U has a 16.5/33.0 VDC maximum voltage, higher than the BA-5590B/U at 16.0/33.0 VDC. This higher voltage can cause equipment damage. The BA-5390/U has been approved for use in SINCGARS radios (MCSC 101842Z MAR 03). The BA-5390/U thermal switch will trip if exposed to temperatures greater than 190 Degrees Fahrenheit. The BA-5390/U provides approximately 40 percent more run time than the BA-5590B/U. DLA has <u>recently stocked new models</u> of the BA-5590B/U and BA-5390/U. These new models, shown below, have State of Charge (SOC) LED indicators.

BA-5590B/U
6135-01-438-9450
PG (4) $293.15

BA-5590A/U W/SOC
6135-01-523-3037
PG (4) $348.08

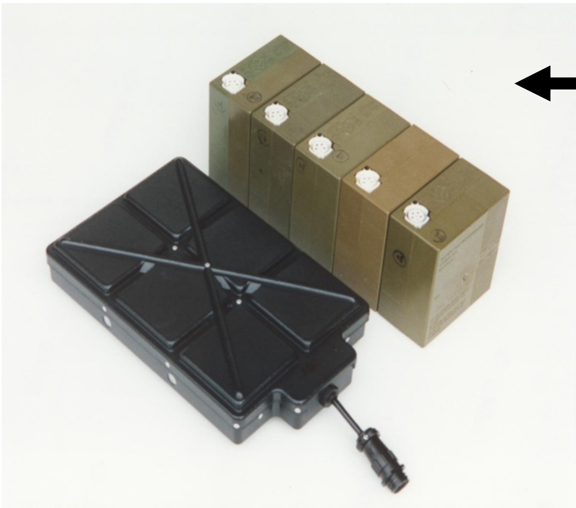
BA-5390/U
6135-01-501-0833
PG (4) $446.03

BA-5390A/U W/SOC
6135-01-517-6060
PG (4) $480.27

State of Charge (SOC) indicators allow users to fully utilize battery capacity by displaying the remaining battery SOC in segments from 20% to 80%.

TAB B

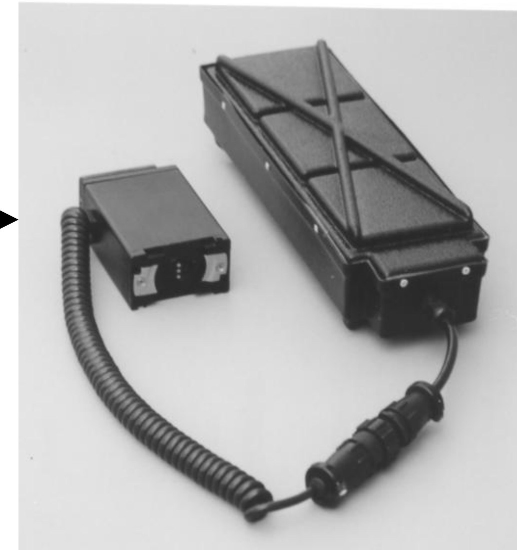
ZINC-AIR PRIMARY BATTERIES AND ADAPTERS



BA-8180/U	BA-8140/U
12/24 VOLT	12 VOLT
800 watts	400 watts
Six pounds	Three pounds

Zinc-air batteries require special adapters. These adapters are re-usable.

Zinc-air batteries must be exposed to air and will not work if submerged.



BA-8140/U with J-6686/U MBITR adapter

SAMPLE PERFORMANCE TIMES

EQUIPMENT	BA-8180/U	BA-8140/U
AN/PRC-119F	5-10 Days	4-6 Days
SINCGARS (A-E)	5-9 Days	4-6 Days
SATCOM HF	5-7 Days	N/A
MBITR (PRC-148)	14 Days	7 Days

ADAPTER	APPLICATION	NSN	PRICE	U/I
J-6687/U	SATCOM/HF	5940-01-516-9787	$505.00	EA
J-6686/U	MBITR (PRC-148)	5940-01-517-3990	$233.00	EA
J-6633/U	AN/PRC-119F ASIP	5940-01-504-3218	$113.78	EA
J-6634/U	SINCGARS (A-E)	5940-01-504-5597	$51.46	EA

J-6633/U

J-6634/U

Zinc-air batteries react with air and experience continual discharge once removed from their packaging.

TAB C

RECHARGEABLE BATTERY OPERATING & STORAGE TEMPERATURE PLANNING INFORMATION

Rechargeable batteries are designed to operate and accept a recharge cycle from -4 degrees F to +122 degrees F (-20 degrees C to +50 degrees C). At low temperatures, they may operate, but will not accept a recharge cycle. Use primary batteries when temperatures outside these specifications are encountered.

Storage temperatures for rechargeable batteries should not exceed -4 degrees F to 122 degrees F. In hot climates, keep storage temperatures as low as possible. High storage temperatures will ruin a battery. Generally, the cooler the better.

Charging should occur above 40 degrees F. In temperatures below 40 degrees F, the batteries will take much longer to charge and may not charge fully. Batteries left in temperatures below -4 degrees F must be thawed before charging or they may vent. Allow batteries to thaw for at least six hours.

Stored rechargeable batteries will permanently lose capacity . . even faster in HOT environments . . . so . . charge them at least every six months or better yet . . USE THEM!

WHEN WORKING WITH RECHARGEABLES

USE THEM OR LOSE THEM

SECONDARY BATTERIES (RECHARGEABLE)

BATTERY NAME	EQUIVALENT	BATTERY NSN	U/I	FY-07 PRICE	ADAPTER REQ FOR SPC	ADAPTER REQ FOR VMC
BB-2590/U	BA-5590	6140-01-490-4316	EA	$295.18	J-6358B/P	J-6520A/U J-6581/U
BB-390B/U	BA-5590	6140-01-490-4317	EA	$242.59	J-6358B/P	J-6520A/U J-6581/U
BB-388A/U	BA-5588	6140-01-490-4313	EA	$68.23	J-6357A/P	J-6520A/U
BB-326/U	BB-516A/U	6140-01-533-7674	EA	$91.07	J-6356/P	J-6520A/U
BB-503A/U	N/A	6140-01-419-8193	EA	$80.10	J-6355/P	
BB-2847A/U	BA-5347	6140-01-493-8092	EA	$94.75	J-6354/P	J-6520A/U
BB-557/U	BA-5557	6140-01-071-5070	EA	$93.63	J-6523A/P	J-6584/U
BB-2557	BA-5557	6140-01-490-5387	EA	$160.45	J-6523A/P	J-6584/U
BB-2600A/U	BA-5600	6140-01-490-4311	EA	$139.92	J-6521/P	J-6584/U
BB-2800/U	BA-5800	6140-01-490-5372	EA	$117.82	J-6587/P	J-6520A/U
AA Rechargeables			EA		J-6589/P	
MBITR Battery		6140-01-487-1153	EA	$174.25	J-6588/P	J-6584/U

J-6589/P

SPC with various battery adapters

TAB E

SECONDARY BATTERIES (RECHARGEABLE)

The most widely used secondary (rechargeable) batteries are the BB-390B/U and the BB-2590/U.

BB-390B/U

Nickel Metal Hydride.
4 year warranty.
Lasts 16 to 20 hours in SINCGARS radios.
Life cycle 3 – 5 years.
Requires periodic conditioning.

Lithium-Ion. Desert tan. Weighs one pound less than the BB-390B/U and has a higher capacity.
Does not require conditioning.
4 year warranty.

BB-2590/U

The BB-390B/U and the BB-2590/U are warranted for four years. Check the manufacturing date (7/03) to the left of the S/N. The first digit is the month, the second is the year. This date starts the warranty clock.

The BB-2590/U is approved for use in the AN/PRC-104, AN/PRC-113, AN/PRC-117, AN/PRC-150, AN/PSC-5, KY-57, KY-99, and all SINCGARS models. Note: The BB-2590/U is NOT APPROVED for use in the Javelin Command Launch Unit. The higher voltage of the BB-2590/U will damage the CLU control unit.

TAB F

ALTERNATIVE POWER EQUIPMENT DATA CHART

NOMENCLATURE	MODEL	TAMCN	NSN	FY-07 PRICE
BATTERY CHARGER/ANALYZER CASP 2000H(M)	PP-8333/U	A7700	6130-01-341-2073	
VEHICLE MOUNTED CHARGER (VMC)	PP-8481B/U	H6002	6130-01-527-2726	$2,272.00
SUITCASE PORTABLE CHARGER (SPC)	PP-8498/U	A0012	6130-01-495-2839	$2,028.00
SINGLE RADIO POWER ADAPTER 24V	MRC-93	H7706	6130-01-520-8178	$1,994.85
SINCGARS SINGLE POWER ADAPTER (SSPA)	PAC-216/U	H7710	5985-01-465-2867	$2,495.00
MULTI-SINCGARS POWER ADAPTER (MSPA)	ASAPS-6 / SNAP 6	H7715	6130-01-458-4041	$2,375.00
MULTI-RADIO POWER ADAPTER (MRPA)	ASAPS-SC / SNAP 6CC	H7705	6130-01-473-0349	$2,260.00
QP-1800 System W/NATO Slave cable and case	QP-1800	H0004	TBA	$2,555.00
DISCHARGE CAP	PP-8497/U	N/A	6130-01-490-4310	$66.54
SPC SLAVE CABLE	J-6362A/U	N/A	5940-01-501-6714	$172.09
SPC NATO SLAVE Y-CABLE	CX-13560/G	N/A	5995-01-505-7883	$65.05
MBITR BATTERY BOX for AN/PRC-148	MRC-41	N/A	McDowell Corp	$1,371.46
MBITR BATTERY CELL HOLDER for AN/PRC-148		N/A	6160-01-487-1151	$157.00
SCAVENGER		N/A	6130-01-539-0646	$308.00
AN/PRC-119F (ASIP) POWER ADAPTER	VB-90		IRIS Technology	$2,045.00

In order to be effective on the battlefield, a unit must be able to Move, Shoot and Communicate. Early into the invasion of Iraq, severe shortages of BA-5590/U batteries almost delayed combat operations. Units can mitigate future problems by training with and employing alternative power. Become BATTERY INDEPENDENT.

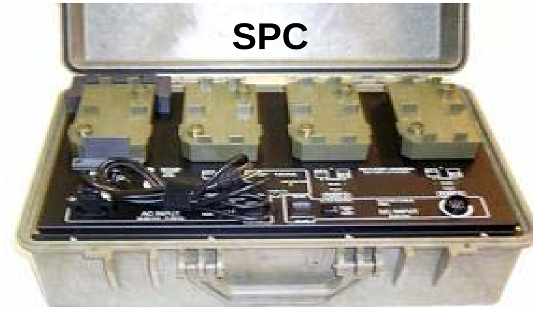
TAB G

BATTERY CHARGERS

PP-8333/U CHRISTIE BATTERY CHARGER/ ANALYZER

Programmable.
Requires periodic calibration.
SL-3 cables support the BB-516, BB-586, BB-557, BB-590, BB-390B/U, BB-588, and BB-699. Other cables are available (refer to PP-8333/U data sheet in TM-12359A-OD located in the Electronic Tool Box).
Will not charge the BB-2590/U.
Requires MI-09591A-25/1B for the BB-390B/U.

PP-8498/U SUITCASE PORTABLE CHARGER



Sequentially charges up to eight batteries (two at a time) in approx. 8 hours. Operates from AC or DC. Comes with AC cable, DC cable must be ordered. Will charge the BB-2590/U. Will not charge the BB-590. Software upgradeable.

PP-8481B/U VEHICLE MOUNTED CHARGER

Mounts in a tactical vehicle. Charges two batteries at a time and moves to the next two in queue. Operates from DC or AC. Comes with AC & DC Cable. Will charge the BB-2590/U. Will not charge the BB-590. Software upgradeable.

See TAB I for SPC/VMC adapter chart.

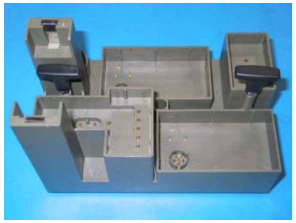
See TAB J for SPC/VMC software updates.

Both the SPC & VMC are equipped with VEH battery low voltage detection & cutoff protection.

SPC/VMC CHARGER TO ADAPTER REF TABLE

Red indicates UNIVERSAL ADAPTERS which are designed to hold various different types of batteries at the same time.

ADAPTER	ADAPTER NSN	FY-07 PRICE	U/I	RECHARGEABLE BATTERY	SPC	VMC
J-6358B/P	5940-01-501-3312	$79.62	EA	BB-2590/U BB-390B/U	X	
J-6357A/P	5940-01-493-6388	$28.14	EA	BB-388A/U	X	
J-6356/P	5940-01-427-9183	$28.14	EA	BB-326/U (old BB-516A/U)	X	
J-6355/P	5940-04-427-9247	$44.96	EA	BB-503A/U	X	
J-5354/P	5940-01-427-9278	$60.47	EA	BB-2847A/U	X	
J-6523A/P	5940-01-492-7238	$46.25	EA	BB-557/U BB-2557	X	
J-6521/P	5940-01-467-8813	$44.96	EA	BB-2600A/U	X	
J-6587/P	5940-01-493-6750	$43.66	EA	BB-2800/U	X	
J-6589/P	5940-01-493-7622	$84.39	EA	AA BATTERIES	X	
J-6588/P	5940-01-493-6751	$68.88	EA	MBITR BATTERY (PRC-148)	X	
J-6520A/U	5940-01-493-8744	$331.64	EA	BB-2590/U BB-390B/U		X
J-6520A/U	5940-01-493-8744	$331.64	EA	BB-388A/U BB-2800/U		X
J-6520A/U	5940-01-493-8744	$331.64	EA	BB-516A/U BB-326		X
J-6520A/U	5940-01-493-8744	$331.64	EA	BB-2847A/U		X
J-6581/U	5940-01-494-7116	$312.31	EA	BB-2590/U BB-390B/U		X
J-6584/U	5940-01-494-7120	$312.31	EA	BB-2557B/U BB-557/U		X
J-6584/U	5940-01-494-7120	$312.31	EA	BB-2600A/U MBITR		X



J-6584/U Universal Adapter for the VMC.

TAB I

BATTERY CHARGER ANCILLARY DEVICES

J-6362A/U DC slave cable for the PP-8498A/U (SPC). Disregard the smaller cable (attached), it is only used with the legacy PP-8444A/U.

CX-13560/G connects two SPC's to one DC slave cable (J-6362A/U).

PP-8497/U Self-Discharge Device (CAP), black, tan or dual colored, is used to discharge (condition) the BB-390B/U or "Quick Check" that both 12-volt sections of the battery are working. When used with the BB-2590/U, it is only used to provide a "Quick Check". The BB-2590/U does not require conditioning.

SPC/VMC SOFTWARE UPDATES

The current version of software for the SPC is 3_30_.00.exe program E. Software updates can be downloaded from the U.S. Army rechargeable battery web site (TAB N) or call your supporting FSR (TAB Q). As new SPC adapters are developed supporting software updates will be published. The VMC, although software upgradeable, does not require a software upgrade at this time.

TAB J

12/24V RADIO POWER ADAPTERS

SINCGARS SINGLE POWER ADAPTER (SSPA) or AN/PAC-216

Replaces battery box. Energizes one SINCGARS radio using AC input. Built in UPS. Does not operate off DC power.

12V

POWER ADAPTER, 24V MRC-93

24V

Replaces battery box. Energizes one 24V radio using AC or DC input.

The MRC-93 is UPS capable when any BA-5590 equivalent battery is inserted into the adapter. Will not charge batteries used in this configuration. Warranted for 4-years.

MULTI-SINCGARS POWER ADAPTER (MSPA) or ASAPS-6

Energizes up to six SINCGARS radios using AC or DC power.

12V

MULTI-RADIO POWER ADAPTER (MRPA) or ASAPS-SC/SNAP 6CC

Energizes up to six 12V radios using AC or DC power. Supplied with six 12-foot radio power cables.

12V

The MSPA & MRPA are more effective when connected to both AC & VEH DC. While operating from the AC source, the VEH battery acts as an UPS. The AC power also maintains the VEH battery SOC.

TAB K

COMMERCIAL-OFF-THE-SHELF (COTS)

VB-90 Power Adapter for the AN/PRC-119F (ASIP).

SCAVENGER – recharge AAs in 100 minutes scavenging unused energy from BA-5590 equivalent batteries.

MRC-41 – holds primary or rechargeable battery, powers the AN/PRC-148.

Products pictured (TAB L) have not been tested to MIL SPEC standards.

Buyer beware, many vendors will attempt to sell products they claim to meet military specifications. They may or may not fail at high or low operating temperatures or in field environments.

Any product containing Lithium must be tested and approved for Marine Corps use under the Navy Lithium Battery Safety Program.

AN/PRC-148 (MBITR) Battery Cell Holder, holds DL2/3A, provides ten hours of operation.

TAB L

DC TO AC INVERTERS

The QP-1800 is a semi-ruggedized 1800W DC to AC (True Sine Wave) inverter that enables operation of 115 VAC powered devices from vehicle power (24 VDC). The QP-1800 connects to the vehicle using a supplied NATO SLAVE cable.

BATTERY SAFETY

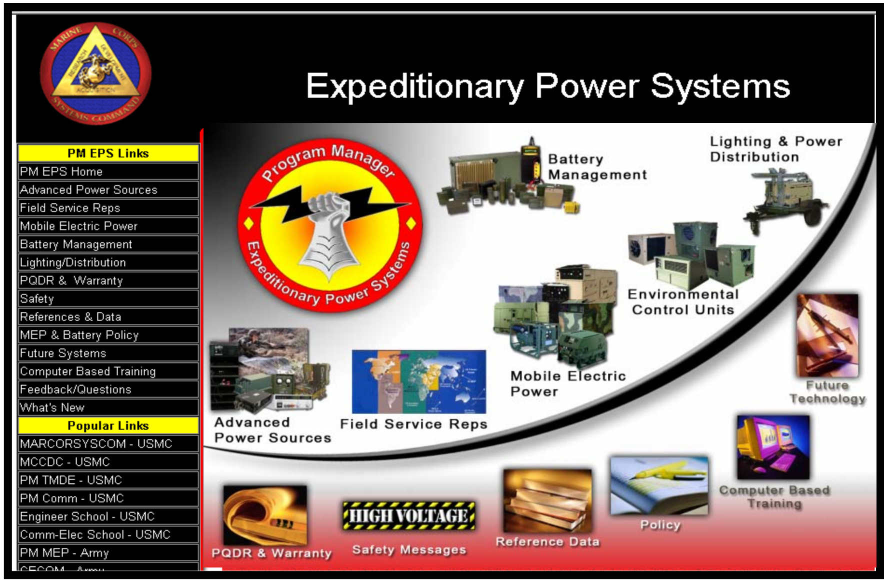
When used incorrectly or mishandled, batteries can be hazardous. Be familiar with the material safety data sheets for all battery types.

TAB M

WEB SITE'S

U.S. Marine Corps
Program Manager
Expeditionary Power Systems
Marine Corps Systems Command

www.marcorsyscom.usmc.mil/sites/pmeps



U.S. Army
Rechargeable Battery
Program

www.monmouth.army.mil/cecom/lrc/lrchq/power/rechargebat.html

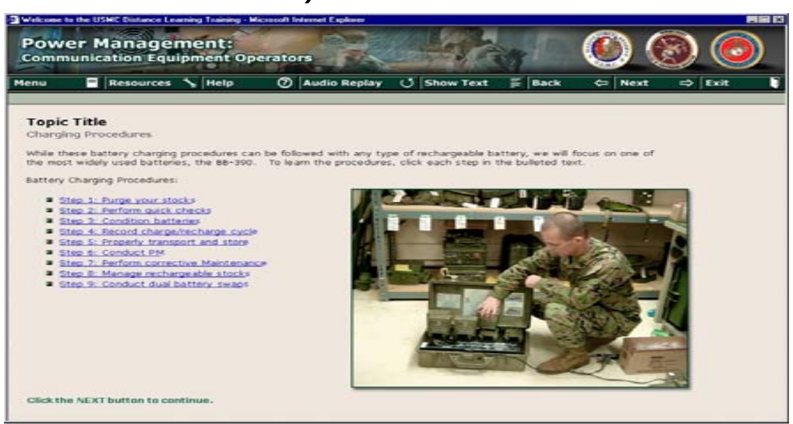
TAB N

TRAINING

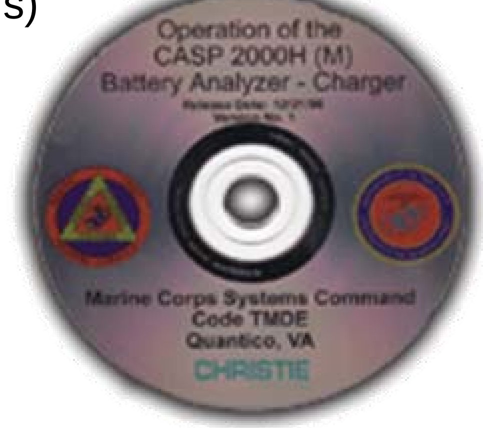
Battery Maintenance and Sustainment Systems (CD is available from FSR's)

12 Volt and 24 Volt Radio Adapter and Power Supply (CD is available from FSR's)

Power Management for Communication Equipment Operators (available at www.marinenet.usmc.mil, course 0612AO)



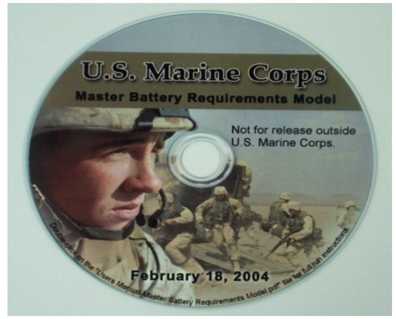
PP-8333/U, Christie Casp 2000H Battery Charger, operator's interactive CD (available from FSR's)



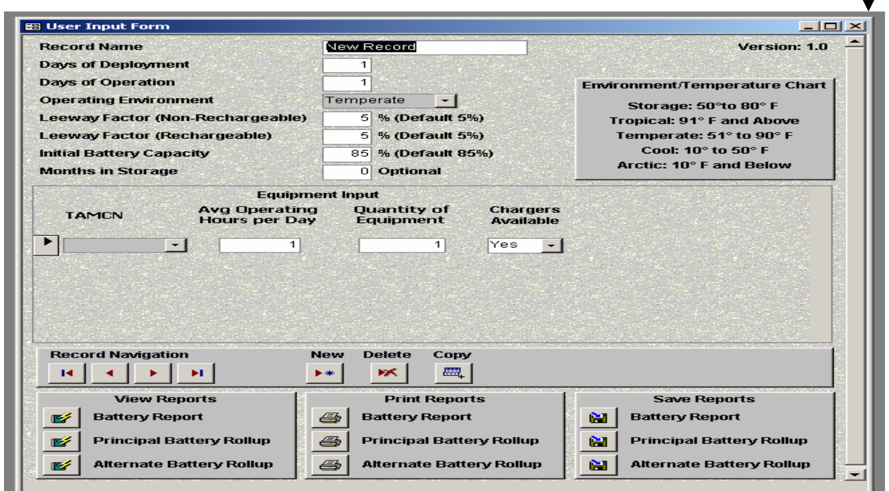
TAB O

BATTERY PLANNING TOOLS

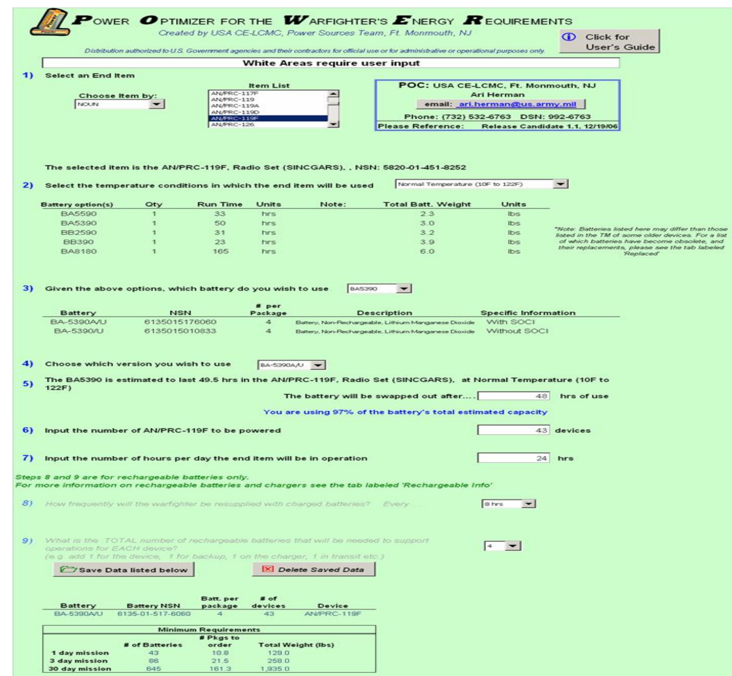
Master Battery Requirements Model



> Battery planning tool
> Standard record of T/E equipment that uses batteries
> Have exercise specific records
> Standard reports and back-up
> Run scenario's
> **MUST BE TRAINED in use prior to issue**
> Available from your supporting FSR



POWER 1.1 Battery Calculator is an excel data base application developed by the U.S. Army to estimate communications equipment battery requirements. It is available from your FSR or by contacting WebPubEPS@mcsc.usmc.mil.



TAB P

POINTS OF CONTACT

PM EPS FIELD SERVICE REPRESENTATIVES

I MEF CAMP PENDELTON
Mr. Talmadge Jackson
talmadge.d.jackson.ctr@usmc.mil
(760) 725-4923

II MEF CAMP LEJUENE
Mr. Ken Copeland
ken.copeland@usmc.mil
(910) 451-1902

III MEF CAMP KINSER
Mr. John O'Brien
john.o'brien@usmc.mil
011-81-611-737-5023 (DSN 637-5023)

MEF FORWARD
Mr. Daryl Wilson
WilsonDK@cssemnf-wiraq.usmc.mil
DSN 302-3640-220 (Iraq)

PM EPS MARINE CORPS SYSTEMS COMMAND

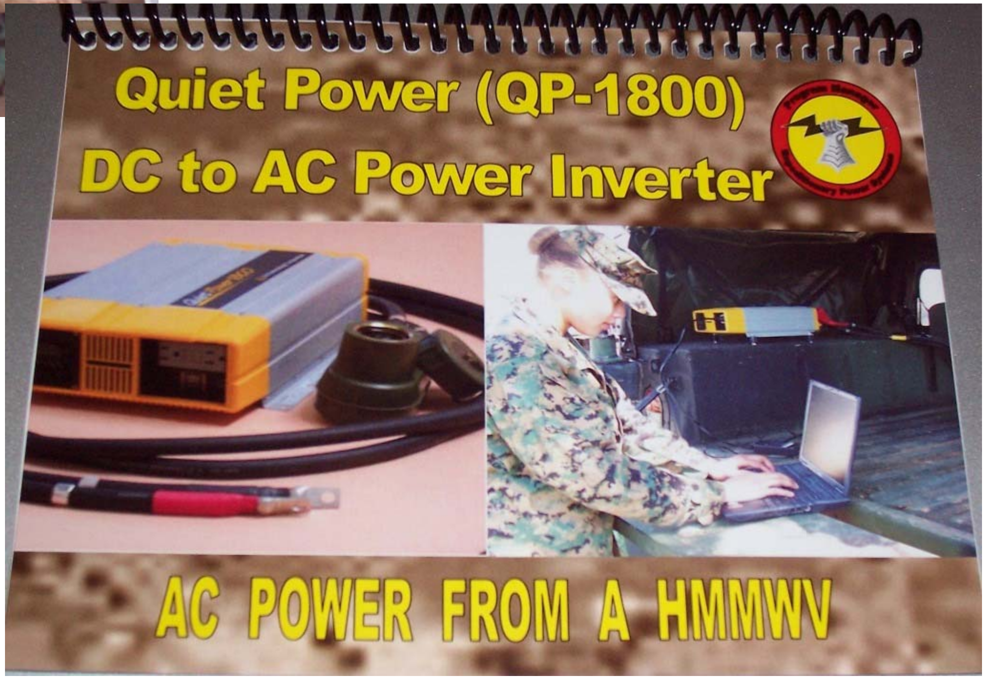
ADVANCED POWER TEAM LEADER
Ms. Joanne Martin
joanne.martin@usmc.mil
(703) 432-3584 (DSN 378-3584)

Send questions to PM EPS MCSC at

WebPubEPS@mcsc.usmc.mil

U.S. ARMY RECHARGEABLE BATTERY PROGRAM
Mr. Don Brockel
donald.brockel@us.army.mil (732) 532-4948

WebPubEPS@mcsc.usmc.mil



QUESTIONS

mbissonnette@mkisystems.com

Servicing
Hawker Vehicle Batteries with Standard Battery Charging and Test Equipment

Mr. Fred Krestik
TARDEC

2007 Joint Service Power Expo

The Hawker Battery

Hawker Armasafe Plus Battery
NSN 6140-01-485-1472

Absorbent Glass Mat (AGM) technology

Recoverability

Hawker batteries have proven to be *highly* recoverable using standard charging equipment:

- Ft. Drum March 2006: >90% of Hawkers sent to DOL shop were successfully recovered using standard battery shop buss bar charging equipment.
- Ft. Hood May 2006, 2 pallets of Hawker batteries from DRMO were sent to TACOM for analysis: ≈90% were recovered using std. chargers/methods.

TB 9-6140-252-13

The technical information presented is taken from Technical Bulletin TB 0-6140-252-13 titled:

Field and Sustainment
Maintenance and Recovery Procedures
For
Automotive HAWKER ARMASAFE Plus Battery
NSN 6140-01-485-1472

Required Equipment

Test Equipment:

1. Multimeter or voltmeter: any type that reads in 1/10th volt increments. (Clamp-on ammeter function a plus.)

2. Battery analyzer (e.g. Midtronics or PulseTech) or heavy duty Load Tester.

Required Equipment

Charging Equipment:

- Any charger with constant voltage output (rated at 12VDC or 12/24VDC) that can apply a charge to one or more batteries at a time using alligator clamps or NATO slave connector.
- Most modern chargers have settings/capabilities for AGM batteries.
- If in doubt, test charge voltage.
- Constant current chargers are not recommended.

Charge Voltage Test

To Verify Charger Output Voltage:

1. *Attach charger to any fully charged (6TMF or Hawker) battery.*

2. *Apply power and wait a few minutes until ammeter reads ≈ 1 amp, and measure voltage across battery.*

3. *If voltage reading is > 15 VDC (> 30 VDC across series pair/NATO connector) do not use on Hawker batteries.*

Pre-Charge Inspection

1. Check top, sides, and bottom for damage.
   (i.e. cracks, dents, leaks, or swelling)

2. Check that the battery case and lid are sealed.

3. Make sure terminals aren’t melted, bent or
   damaged.

4. Check for missing vent caps.

Mark and immediately dispose of batteries damaged as listed above.

Pre-Charge Inspection

Cell Vent Caps

Check that all vent caps are in place (flush) and do not appear to be elevated. Gently tap any elevated vent caps back into place and mark them with an “R” with a permanent marker. If a marked vent cap elevates again during charging or operation, dispose of the battery.

Pre-Charge Testing

1. *Clean corrosion from battery terminals with a wire brush.*
2. *Using a voltmeter set to the lowest voltage range above 15 VDC, test the Open Circuit Voltage (OCV) and mark the OCV in pencil or chalk on the top of the battery.*
3. *If a battery analyzer is available, use it to determine if any internal damage exists. Many analyzers will not operate if the battery voltage is very low. If no reading is given or no internal damage is indicated, charge the battery for 24 hours and retest.*

Charging Procedures

Charging Procedures Overviews:

- **Buss Bar Charging Multiple Batteries**
- **Single Battery or “Roll Around” Chargers**

WARNING:
The Charging Procedure Overviews that follow are overviews only. They do not include safety related information. Refer to TB 9-6140-252-13 for more detailed information and procedures.

Overview: Buss Bar Charging Procedures

Checklist summary:

1. *Never mix battery types on a buss bar.*
2. *Group batteries by OCV ranges: 0 – 5.9V, 6.0 – 9.9V, 10V and up.*
3. *Set buss bar voltage between 14.7V and 15.2V.*
4. *Allow at least 10 Amps per battery, e.g. 100 Amp buss bar charger can support 10 batteries max.*

Overview: Buss Bar Charging Procedures

1. *Connect the batteries to the buss bars*
2. *Charge the batteries at least 24 to 48 hours*
3. *Check daily (recommend more frequently) for excessive heating, gassing, leaking, and proper voltage applied.*
4. *Immediately remove any battery that shows signs of excessive heat, gassing, leaking, or swelling during charging. Battery should be marked with date and "Charged Tested Bad" , and disposed of.*
5. *Batteries are finished when charge current drops to approximately 1 Amp per battery.*

Overview: Single Battery & "Roll Around" Chargers

1. *Use only chargers that are compatible with AGM batteries. (Refer to charger instructions and the Charger Output Voltage test)*
2. *Set charger to appropriate settings for battery type and voltage. (Refer to charger instructions and instructions in the TB)*
3. *Connect charger to battery posts or NATO slave receptacle.*
4. *Turn on charger and monitor batteries for excessive heat and gassing during the charge cycle.*

Overview: Single Battery & "Roll Around" Chargers

5. *Some chargers automatically turn off at end of charge cycle. Some of these chargers require multiple cycles to fully charge batteries.*
6. *Batteries are finished when charge current drops to approximately 1 Amp.*
7. *"Rest" the batteries for 8 hours and test using a battery analyzer or load tester.*
8. *OCV of "rested" battery may also be used as an indicator of battery state of charge.*

Rested OCV and State of Charge (SOC)

> 12.9 Volts OCV: 95% - 100% SOC
12.7 Volts OCV: about 80% SOC
12.5 Volts OCV: about 60% SOC
12.3 Volts OCV: about 50% SOC
12.1 Volts OCV: about 35% SOC
11.9 Volts OCV: about 20% SOC
11.7 Volts OCV: about 10% SOC
11.5 Volts OCV: about 5% SOC
< 11.4 Volts OCV: 0% SOC

If the battery hasn't "rested" sufficiently after charging, the voltage reading will be a bit higher than normal. If it hasn't "rested" sufficiently after discharging, the voltage reading may be a bit lower than normal.

Servicing Hawker Vehicle Batteries with Standard Battery Charging and Test Equipment

2007 Joint Service Power Expo

Thank-you!

For further information refer to

TB 9-6140-252-13

Or contact: Boyd Dial or Fred Krestik

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DSN 786-2629
586-753-2629
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Fred Krestik
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Vehicle Battery Maintenance Equipment

Joint Service Power Expo

25 April 2007

- Presented by:
- PulseTech Products Corporation
- Mark Abelson
- 800-580-7554, ext. 167
- 817-307-5603 (cell)
- mabelson@pulsetech.net
- www.pulsetech.net

I. Introduction

2D Infantry Division

- During FY-04 spent 1.5 million on Hawker Batteries
- New equipment without NETT
- Stored them for less than 2 Yrs
- Installed batteries without any diagnostic checks – Massive battery failure
- Updated Equipment
- Received training from PulseTech

2D Infantry Divsion

- Recovered over 2K batteries in 60 days
- Saved $750,000
- Reduced battery consumption by 75% over previous FY

- Command attention, equipment and training are the keys to success

What equipment did they use?

- Diagnostic

- <u>490 PT and MBT-1</u>

- Part Nos. 741x490 and 741x800

- NSNs: 6130-01-510-9594 and 6130-01-463-8499

Diagnostic

490 PT and MBT-1

What equipment did they use?

- Corrective Maintenance Equipment

- <u>Pro HD 12/24 Charger and the World Version Plus</u>

- Part Nos. 746 X 800 and 746 X 725

- NSNs: 6130-01-500-3401 and 6130-01-398-6951

Corrective Maintenance

Redi-Pulse Pro HD
Part No. 746x800
NSN: 6130-01-500-3401

Pulse Charger/World Version Plus
Part No. 746x725
NSN: 6130-01-398-6951

263rd Maintenance Company

- “Your products were instrumental in keeping the war-fighters and logistics elements moving in Iraq. We established the first battery mission in the AO North Sector, and have done over 1,500 batteries since October 2006. Your equipment benefits the Army, as we have saved the government over $300,000 in new battery expenditures."

CW3 Paul L. McLaughlin
Senior Automotive Maintenance Officer
263rd Maintenance Company

What equipment did they use?

Diagnostic

490 PT and MBT-1

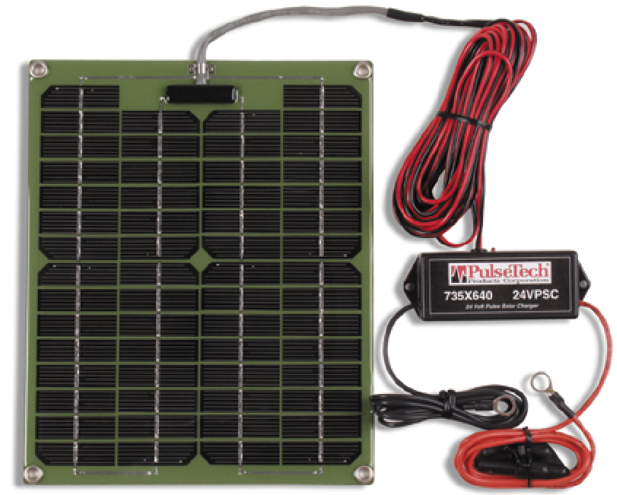
What equipment did they use?

- Corrective Maintenance Equipment

<u>HD Pallet Charger</u>
Part No. 746x820
NSN: 6130-01-532-7711

Preventive Maintenance

<u>24-volt Pulse Charge Monitor System</u>
Part No. 735x643
NSN: 6130-01-497-0964



<u>24-volt Pulse Solar Charger</u>
Part No. 735x640
NSN: 6130-01-487-0035

How are they being used?

- Marine Corps Tactical Quiet Generator (TQG) Modification Instructions (MI’s)

U.S. Air Force War Readiness Program (WRM) i.e. Long Term Storage Program South Korea

- Miscellaneous other applications within DOD and Federal Government (FEMA, BLM, Border Patrol, etc.)

What's New at PulseTech Products?

HD Jump Start

Part No. 746x700

NSN Pending

Common Denominators to Success?

- Patented Pulse Technology
  - Easy to use equipment

- Program Application

- TRAINING!!!!

- Any Questions?

Understanding Military Requirements for Generators

Mr. Jose Antonetti

U.S. Army Aberdeen Test Center

Aberdeen Proving Ground, MD

Broad Application

- Military generator sets support all elements of Department of Defense (DOD) force structure; Army, Navy, Air Force, Marines.
  - Worldwide deployment
  - Highly diverse mission requirements
    - System platforms ranging from ground vehicles to shipboard to airborne.
    - Fixed and semi-fixed facilities
  - Common operation, maintenance, and interface characteristics for use by all DOD components.

Military Unique Requirements

- At a minimum, generators intended for military use must meet unique and interrelated standards for:
  - Environmental performance
  - Safety and human factors engineering (HFE)
  - Survivability
  - Interoperability
  - Logistical supportability
  - Strategic and tactical mobility
  - Technical performance

Environmental Performance

- Harsher conditions generally experienced by equipment in military service.
  - Naturally occurring: Worldwide deployment results in a wider range of extreme conditions:
    - -51 ^{o}C to +49 ^{o}C, operating; -51 ^{o}C to +71 ^{o}C, storage
    - Up to 10,000-ft elevation at 35 ^{o}C (low atmospheric pressure)
    - Solar radiation, thermal and actinic effects
    - Sand and dust, airborne and wind driven particulate
    - Relative humidity, to saturation
    - Ice and freezing rain
    - Salt fog (aggravated corrosion test)
    - Fungus
    - Near strike lightning (NSL)

Environmental Performance

– Induced

- Mechanical shock and vibration
  - – Highway and secondary road and off-road ground movement
  - – Shipboard and aircraft installations
  - – Amphibious and cargo aircraft movements
  - – Airdrop
  - – Externally suspended helicopter loads
- Sand and dust exposure in vicinity of ground vehicles and/or aircraft.
- Thermal shock during air drop, aircraft cargo transport, or deployment from conditioned enclosure.

Safety and HFE

- Meet military standards for safety[1] and HFE[2]

- Emphasis on protecting operators from:
  - Audio noise 85 dB(A) and greater
  - Toxic fumes
  - Energized contacts
  - Sources of thermal energy

- Designed to provide:
  - Common operator controls and indicators
  - Standard interface with military power connections
  - Sufficient workspace and access for all operations and maintenance actions

[1]MIL-STD-882,

[2]MIL-STD-1472,

Survivability/Interoperability

- Survivability:
  - Survive High altitude electromagnetic pulse (HAEMP); result of a nuclear weapon detonated several kilometers in the atmosphere.
  - Be non-detectable by thermal and aural (audio noise) signatures.
- Interoperability:
  - Electromagnetic Interference (EMI):
    - Radiated electrical and magnetic field emissions (RE) that may interfere with other systems and equipment.
    - Susceptibility to fields radiated (RS) by other systems and equipment (i.e. radar, radios, etc.).
    - Susceptibility to signals produced by loads and conducted (CS) along power lines.
  - Installation on or in various military systems; e.g. tactical trailers, shelters, light wheeled, and combat vehicles.

Logistical Supportability

- Supportable within the resources of the DOD system
  - Not create demand for new operation or maintenance skills (training impact)
  - Minimize need for special tools and unique repair parts (supply impact)
  - 24 volt, direct current, electrical system common to all military ground systems (interoperability)
  - Multi-fuel operation
    - Diesel fuel 1 and 2, and arctic (DF-1, DF-2, DF-A)
    - Jet plane fuel 5 and 8 (JP-5 and JP-8)
    - Referee grade with more contaminants than commercially available sources

Strategic and Tactical Mobility

- Meet the interface standard for movement by assets of the Defense Transportation System (DTS)[1]
  - Railroad
  - Ship
  - Highway
  - Military cargo aircraft (internal transport)
  - Helicopter (internal and externally suspended load)
- Equipped with dedicated lift and equipment tie-down provisions
- Palletized with forklift slots

[1]MIL-STD-209K, Interface Standard for Lifting and Tiedown Provisions, 22 February 2005

Technical Performance: Commercial Generators

- ISO 8528[1] used to qualify commercial generators: power definitions and test methods analogous to military standards for power quality, but not exact.

- ISO 8528 used as general guidance for commercial generator qualifications vs. stringent mandates of military standards.

- Most commercial generators rated at unity power factor (1.0, no reactive loading) vs. military requirement for standard rating at 0.8 power factor.

[1]International Standards Organization (ISO) 8528, Parts 1 through 12, Reciprocating internal combustion engine driven alternating current generating sets, 2005

Benefits of Commercial Generators

- Generally
  - Safe and easy to use
  - Reliable
  - EPA emissions compliant
- Widespread commercial network for support
  - Most product lines use common spares and expendables
  - Large aftermarket of components
- Core generator elements – engine, alternator, controls – relatively rugged
- Typically capable of multi-fuel operation

Commercial Generator Limitations

- Power quality issues
  - Excessive deviation and harmonics of voltage waveforms
  - Stability, regulation, transient performance below standards for basic military utility power
  - Can not function in certain climatic extremes without performance degradation
- Operational issues; not ‘greened’
  - Audio noise, quiet, in a bigger footprint
  - Pronounced thermal signature
  - Exceeds military limits for radiated electromagnetic emissions

Limitations, Cont'd

- Configuration issues
  - Controls and indicators not standardized to military format
  - Lack fittings for forklift handling, lift, and/or equipment tie-down for rail/air/ship movements
  - Unique electrical connections
  - Often lack 24 volt electrical system
  - No NATO[1] connector for 'jump' starting
  - Spare parts and expendables not in military stock
  - Susceptible to wind driven sand/dust (desert operations)
  - Vulnerable to HEAMP and chemical-biological agents
  - Lack high capacity fuel/water separation
  - Shock isolation insufficient for off-road/tactical environment

[1]NATO – North Atlantic Treaty Organization

Technical Performance: Military Generators

- Military power requirements are typically more stringent and set in finer increments than ISO 8528.
- Critical applications are more widespread in the military; being offline can produce more serious consequences than for most commercial systems.
- These factors accommodated in military standard 1332, Revision B[1] (MIL-STD-1332B); required for military generators

[1]MIL-STD-1332B, Definitions of Tactical, Prime, Precise, and Utility Terminologies for Classification of the DOD Mobile Electric Power Engine Generator Set Family, reinstated with Notice 2, 10 July 2001

Military Generator Categories

- MIL-STD-1332B categories reflect DOD mission diversity; accommodating specialized requirements
- Types:
  - Type I, Tactical (light, small, mobile)
  - Type II, Prime (semi-fixed)
- Classes:
  - Class 1, Precise (critical applications)
  - Class 2, Utility (general purpose; three sub-classes ranging from 2A commercial equivalent to 2C general utilitarian)
- Modes:
  - Mode I, 50- or 60-Hz
  - Mode II, 400-Hz
  - Mode III, 60-Hz
  - Mode IV, 28 volt direct current

Common Ground: Power Quality

- Characterization of generator output common to MIL-STD-1332B and ISO 8528:
  - Voltage and frequency regulation
  - Voltage and frequency stability
  - Voltage and frequency transient performance
  - Voltage waveform deviation factor and harmonics
  - Voltage phase balance.
- Forms basis for adaptation of commercial generators to military applications.

Technical Performance

- Verified through testing in MIL-STD-705C[1, 2]
- MIL-STD-705C methods accommodate numerous natural and induced environmental conditions.
- Dedicated test facility at ATC for MIL-STD-705 testing.
- Major range and test facility for all other aspects of generator testing required for military acceptance.

[1]MIL-STD-705C, Generator Sets, Engine Driven, Methods of Tests and Instructions, 24 April 1989
[2]Pending revision D.

ATC Related Facilities

Major Missions Include:

- Automotive – Wheeled & Tracked Vehicles
  - Conduct 80% of the Army Automotive Testing.
- Firepower
- Survivability/Lethality
- Warfighter
  - Soldier Systems and Support Equipment
  - Training Exercises
- Military Environmental Technologies
- Maritime Systems

Facilities

APG
Range
Commander

Range = 66K Acres
(½ Land, ½ Water)

103 Miles of Shoreline With 60 Miles
Adjacent to Live-Fire Ranges
with MOUT Facility

Water Depths 2-14’

Open Air Ranges w/ Modular
Instrumentation Suites

Traditional Laboratories w/ Advanced
Tools

Fabrication Facilities & Professional
Craftsman Shops

Isolated / Secure / Hardened Surface
& Sub-surface Opportunities

Temperate Zone

Real-Time MET

Airfield with Landing Capabilities
for any Military Aircraft

Generator Test Facility

- Outdoor test area to support performance and endurance tests of engine-generator sets as specified in MIL-STD-705 and ISO 8528
- 20 concrete pads/40 test stations accommodate generators up to 200 kW
- AC resistive-reactive load banks up to 208 kW/154 kVAR on site: greater capacity available
- Test instrumentation, multichannel, automated data acquisition and reduction system
- Higher-capacity generator testing is accomplished with special requirements
- Central monitoring and control station for automated data acquisition and analysis
- Central fuel storage and pumping facility
- Mobile instrumentation trailers for testing at remote sites
- Service buildings for maintenance, modifications, and instrumentation

Mobile Generator Test System

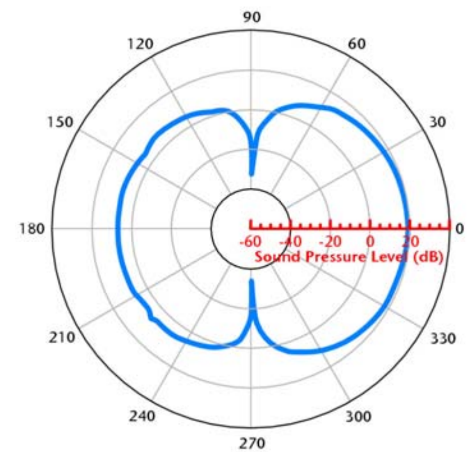
• Complete, self-contained, mobile capability for generator testing to 300-kW, including instrumentation and data acquisition

• The above contains a load bank rated to 208 kW (frequency 50/60/400 Hz) and a control console mounted in shelter.

• The semi-trailer contains a 300 kW AC and DC (frequency 50/60/400 Hz), a work area, and a control console mounted in shelter

Human Factors Engineering (HFE)

Airflow Testing, Mobile Data Acquisition System, and General Capabilities



- Mobile instrumentation vans to support various HFE tests
- Two 6.5-kW generators for internal utilities and instrumentation
- Impulse and steady state noise tests, including hearing conservation, drive-by, and aural non-detectability
- Measure gaseous flow rates and pressures, and fluid temperatures and velocities
- Speech intelligibility
- Anthropometric characterization of test participants
- System design review

Analytical Chemistry Laboratory

- Various analytical techniques are utilized to identify and quantify the chemical composition of samples from various sources. The analysis employs standard methods from analytical and environmental chemistry. The instrumentation utilized is as follows:
  - High Performance Liquid Chromatography (HPLC)
  - Atomic Spectroscopy (AA-ICP)
  - Gas Chromatography Mass Spectrometry (GC/MS)
  - Ion Chromatography (IC)
  - Fourier Transform Infrared Spectrometry (FTIR)

- Examples of procedures are as follows; other procedures can be developed:
  - Ion Analysis: sulfate, phosphate, chloride, fluoride, nitrate, nitrite
  - Wet Chemical: pH, conductivity, total dissolved solids, hardness, turbidity, dissolved oxygen, chemical oxygen demand, total coliforms
  - Propellant Analysis: solid and liquid, effective stabilizer level, moisture, volatiles
  - Explosives identification
  - Elemental: carbon, hydrogen, nitrogen, oxygen
  - Airborne particulate
  - Polynucleic aromatic hydrocarbons (PAH)
  - Toxicity Characteristic Leaching Procedure (TCLP) and other leaching procedures
  - Metals in wastewater, drinking water, and soil; also lead in paint
  - Total petroleum hydrocarbons (TPH) in wastewater
  - Volatile organic compounds (VOC) and Semivolatile organic compounds
  - Identification of unknown samples

Fuels Laboratory (Chemistry)

- The Chemistry Team Laboratory is certified by the Army Petroleum Center as a fuel testing laboratory
- Fuels are tested to assure compliance to standards for use in test items and vehicles
- Analysis of diesel and kerosene-type fuels includes:
  - Distillation range
  - API and specific gravity
  - Flash point (closed and open cup)
  - Cetane index
  - % Water by Karl Fisher
  - Particulate contamination
  - Sulfur
  - Cloud point
  - Pour point
  - Freeze point

Oils Laboratory (Chemistry)

- Oils and lubricants are analyzed and tested to determine the wear of metals components in test items. Changes to the physical properties of the oils and lubricants are monitored

- Surveillance of lubricants during testing can help predict wearing of metal parts and help predict component failure.

  - The surveillance program can also help determine service intervals by assessing other physical properties such as viscosity

- Foreign oils and fuels are analyzed and a U.S. replacement fluid is determined for continued operation of unique test vehicles

- The Chemistry Team Laboratory is certified in the JOAP/AOAP as a special laboratory for oils analysis - procedures include:
  - Wear Metals by Spectroscopy
  - Particle Contamination
  - Particle Analysis by Ferrography
  - Acid/Base Number
  - Viscosity
  - Fluid Contamination by FTIR

Lift and Tie-Down Facility

• Utilized to test the lifting and tie-down provision capacity of military vehicles and generators in accordance with MIL-STD's 209 and 913

• Various devices are provided to impact test loads in vertical, longitudinal, and lateral directions:

- 55-ton overhead chain hoist
- Remotely controlled 60-ton hydraulic load application system
- Airbag inflation system
- Mobile cranes of varying capacities up to 250 tons

• On site ballistic proof test control room provides:

- Protection for test personnel, test sponsor and manufacturer representatives
- Video camera/VCRs for real-time monitoring and recording of test load applications

Rail Transport Facility

- Testing per MIL-STD-810 to ensure compliance with Military Traffic Management Command transportation certification requirements
- Fully instrumented (velocity, shock levels) test capability
- On-site locomotive and standard railcar equipment
- Covered railcar loading/unloading and tie-down facility with stocked supplies of rigging materials, tools, and wood-working machinery for producing required chocks and cribbage
- Still and video photographic coverage, including high-speed video

External Air Transport

- Testing per MIL-STD-913 to ensure compliance with certifying agency for EAT, U.S. Army Soldier Systems Command (formerly The U.S. Army Natick Research, Development and Engineering Center)
- Static lifts of aircraft slinging configurations by crane prior to flights to verify suspension orientation and clearances
- On-hand supply of approved rigging materials
- Army CH-47D Chinook and Marine Corps CH-53E Sea Station helicopters with experienced aircrews and riggers
- Aerodynamic flight tests conducted at Phillips Army Airfield, APG
- Still and video ground/aerial photography documentation
- Instrumentation available for test items and slings if desired

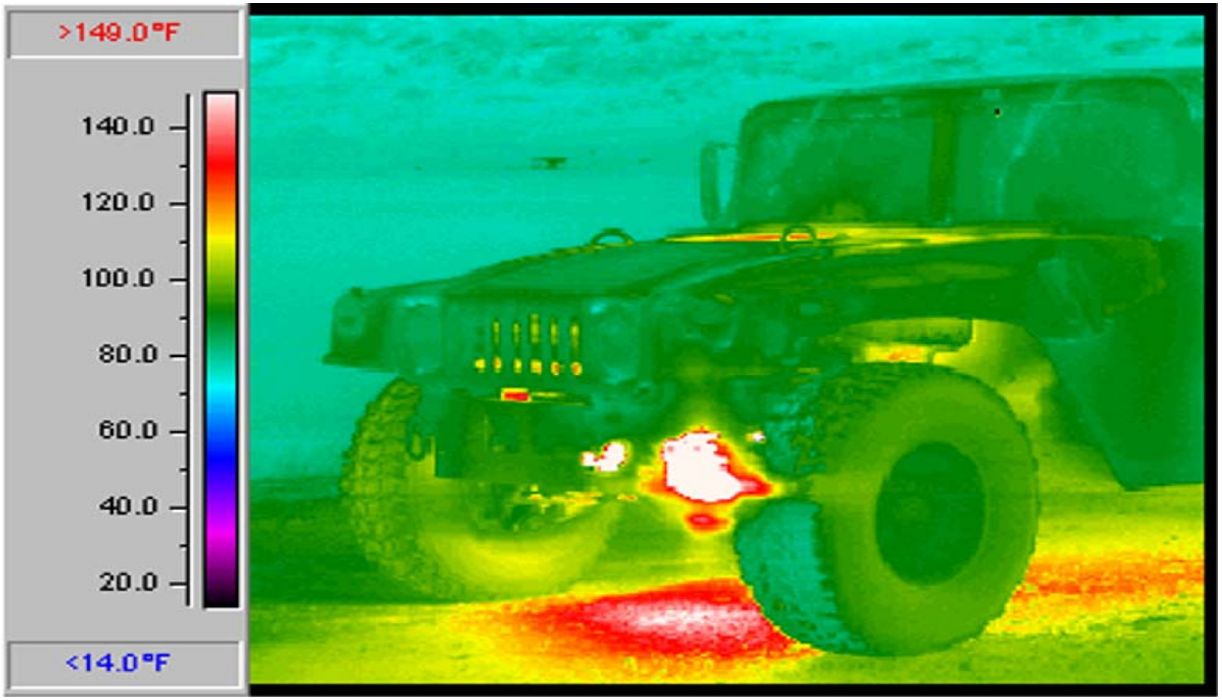
Internal Air Transport

- Access to all U.S. Air Force transport aircraft (C-130, C-141, C-5, C-17), pallets, rigging, and material-handling equipment for demonstrating and validating loading procedures for vehicles and equipment as required for Wright-Patterson AFB certification of IAT
- APG Phillips Army Airfield spacious facilities (8000-ft main runway and up to 800-ft ramp areas) accommodate all transport aircraft for on-site evaluations
- Proximity to local Maryland National Guard (Baltimore), Andrews Air Force Base (Washington, DC area), and Dover AFB (Delaware) for off-site evaluations
- Experienced active-duty loadmasters assist in evaluation and resolution of potential air transportability issues
- Dimensional and clearance measurements, still and video photography provided to document evaluations

Electromagnetic Interference Test Facility (EMITF)

- The EMITF delivers high degrees and ranges of attenuation to test military systems and subsystems against controlled electromagnetic military standards
- One of the largest facilities of its type, the facility measures 94' L x 60' W x 28' H, making it large enough for combat vehicles, tactical trucks, large caliber weapons systems, and helicopters and small enough for hand-held binoculars
- Multiservice test facility
- Testing from 16 Hz through 40 GHz
- Susceptibility levels up to 200 V/m
- MIL-STD, SAE, CISPR (Comité International Spécial de Perturbations Radioélectriques), and FCC testing
- One access door 16' x 16'; two access doors are 4' x 6'
- Magnetic field attenuation of 40 dB, 14 kHz to 1 MHz
- Electric field attenuation of 90 dB, 14 kHz to 30 MHz
- Plane wave attenuation of 90 dB, 30 MHz to 1000 MHz
- Floor load rating: 18,000 lb./ft^2
- Ventilation: 12,000 cfm

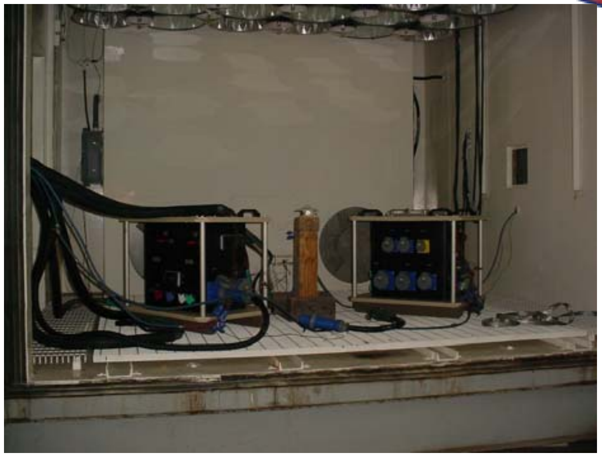
Infrared Thermal Imaging



- ATC has a state-of-the art infrared camera system operating in the 3- to 5-um spectral range
- System is used for real-time documentation of thermal signatures profiles, burning residue identification, and fire ignition/propagation testing

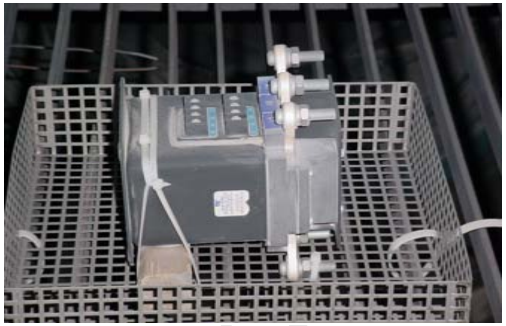
Climatic Simulation Facilities/Capabilities

Blowing Rain



Solar Test

Salt Test



Dust Test

- Facilities provide climate test support requirements of MIL-STD-810F
- Wind machine - Three moveable units generate up to 100 mph winds, 40'
- Wind-driven rain - movable machine produces up to 4 in./hr of rain at up to 50 mph wind
- Temperature-humidity chambers and portable units having temperature from -80 ^{o}F to +200 ^{o}F and humidity up to 100%
- Solar radiation

Environmental Chamber No. 1

- Large controlled-temperature chamber for climatic testing of vehicles, weapon systems, and soldier systems (C4I, generator, materials handling, civil engineering, air and water purification, lift and tie down, bridging/watercraft, tents/shelters) in accordance with MIL-STD-810F
- Chamber is 15' W x 24' L x 10.9' H having a 10.3' x 10' door
- Temperature range from -70 °F to 160 °F
- Used for firing weapons up to 155-mm caliber in extreme conditions
- Sensors detect toxic/hazardous fumes and gases
- Ports for instrumentation cable access

Environmental Chambers No. 2 and 3

- Large controlled-temperature chambers and adjacent conditioning room for climatic tests of vehicles, weapon systems, and soldier systems (C4I, generators, materials handling, civil engineering, air and water purification, lift and tie down, bridging/watercraft, tents/shelters) in accordance with MIL-STD-810F
- Chamber 2 is 10' W x 19' L x 10' H with a 9' x 7' door
- Chamber 3 is 18' W x 28' L x 15' H with a 13' x 11.5' door
- Conditioning room is 23' W x 41' L x 14' H with a 14.5' x 12' door
- Chambers 2 and 3 temperature range of -65 °F to 165 °F
- Conditioning room temperature range of 0 °F to 165 °F
- Firing of weapons up to 155-mm caliber under various climatic conditions
- Toxic gas/hazardous fumes monitor/alarm system

Environmental Chamber No. 4

- Spacious multipurpose facility provides temperature, humidity, icing, thermal shock, salt fog, dust, solar radiation, and altitude test capability, meeting the requirements of MIL-STD-810F
- 40' W x 75' L x 24' H chamber
- Temperature range -70 ºF to 170 ºF with humidity control up to 98%
- Dividable into two 40' x 37' chambers having independent climatic controls
- Each chamber has 16' x 16' door
- 10' x 20' solar radiation area
- Adjacent area for data acquisition and control instrumentation

Munson Test Area

- Automotive field test area consisting of 9 miles of roadways/test courses encompassing 150 acres
- Paved course - 2200'
- Sand course - 500'
- Belgian block course - 3900'
- Wave course - 440'
- Vertical walls - 18" to 42" H
- Slide slopes, 20% to 40%, 100' to 700'
- Simulated loading ramp - 40' , 20^{o}
- Improved gravel road - 10,700'
- Abrasive mud course - 950' L x 240' W
- 2- and 6-inch washboards - 800'
- 2- to 4-inch radial washboard - 240'
- 3-inch spaced bump course - 760'
- Longitudinal slopes, 5% to 60%, 80' to 480'
- Shallow and deep fording basins - 270' L x 6' D, 315' L x 20' D
- Amphibious vehicle swim area (Spesutie Narrows/Chesapeake Bay)

Perryman Test Area

- Level cross-country, secondary, and paved road vehicle endurance and reliability test area
- Six primary test courses cover about 2,000 acres:
  - 3-mile straight and level paved road with turnarounds
  - Two secondary roads, 2.4 miles and 3.2 miles
  - Four cross-country courses of varying severity, 1.8 miles to 5.2 miles
- Off-road courses vary from moderate gravel surfaces to extremely rough terrain including marshy areas
- Supports other vehicle tests, i.e., braking, stability, road vibration, steering, etc.

Churchville Test Area

- Hilly cross-country tracked and wheeled vehicle endurance and reliability test area
- 250 acres with 11 miles of interconnecting roads and test courses
- 7% to 29% grades
- 3-mile and 4-mile winding closed loop courses
- Mud, dust, and gravel surfaces
- Temperate climate
- 4-bay maintenance shop
- Complete coverage with telemetry/on-board instrumentation
- Slopes are prepared by tilling and water supply is available for wetting

Vibration Facility

Vertical Exciter

Horizontal Exciter

- Three remotely controlled electrodynamic vibration systems capable of testing to MIL-STD-810E
- Safety certified for tests of hazardous and radioactive items
- Shock and vibration tests of vehicles, equipment, weapons, and ammunition
- Damping characteristics of vehicle suspension systems
- Ride quality
- Laboratory vibration schedules developed from field data
- Temperature range from -70 ^{o}F to +170 ^{o}F
- Vibration exciter force capabilities up to 40,000 force pounds
- Single axis; three planes

Instrumentation Development

Advanced Distributed Modular data Acquisition System (ADMAS)

- ATC engineers and scientists are recognized at all levels of DoD for their expertise for the application of emerging technologies to current test methodologies and the development of test equipment, measurement instrumentation and test facilities
- Scientific and engineering services for the development and integration of:
  - Measurement instrumentation
  - Test methodologies
  - Test equipment
  - Test related infrastructure
- Development capabilities include, but are not limited to:
  - Concurrent engineering
  - Software
  - Embedded instrumentation
  - Communications
  - Data acquisition and archival
  - Mechanical design
  - Systems integration
  - Custom fabrication
  - System procurement
  - Civil engineering
  - Technical consulting

OUR ULTIMATE CUSTOMER

Tomorrow's Warfighter

Testing of COTS/NDI Products

Joint Service Power Exposition

25 April 2007

Testing of COTS/NDI Products

Joint Service Power Exposition

25 April 2007

Session 10

Introduction

Mr. John O'DONNELL, USMC

Marine Corps Approaches

Mr. John O'DONNELL, USMC

Navy COTS Testing

Mr. Randy Haag, Manger, Power Systems Division NSWC Crane

COTS Testing By the ARMY

Mr. Jose Antonetti , Test Director
US Army Aberdeen Test Center

Testing of COTS/NDI Products

USMC Approach

John O'Donnell

John.h.odonnell@usmc.mil

Joint Service Power Exposition
25 April 2007

Testing For Military Use

- Why COTS ?
- Cheaper
- Get quicker Avoid Development and Qualification
- Vendor handles Configuration and Tech Data Package
- Faster Delivery Schedule

Why Do We Test?

- **The operating environment is more extreme**

  Greater Temperature extremes

  Sand and Dust Rain and Salt Air

  EMI interference issues

  The transportation conditions are more extreme

  The power used for power is from Generators (greater surges sags and phase anomalies)

Transportation

- The Marine profile is based on transportation off road 80% of the time.
- The transportation is in the back of truck
- Units are dropped and transported to extreme altitudes and via watercraft.

Testing

- Road Course Testing
- Loose cargo bounce
- Drop Testing
- Lift and Tie Down
- Environmental
- EMI

Vibration USMC way

DEPARTMENT OF THE NAVY
UNITED STATES MARINE CORPS

Testing

Lift and Tie Down

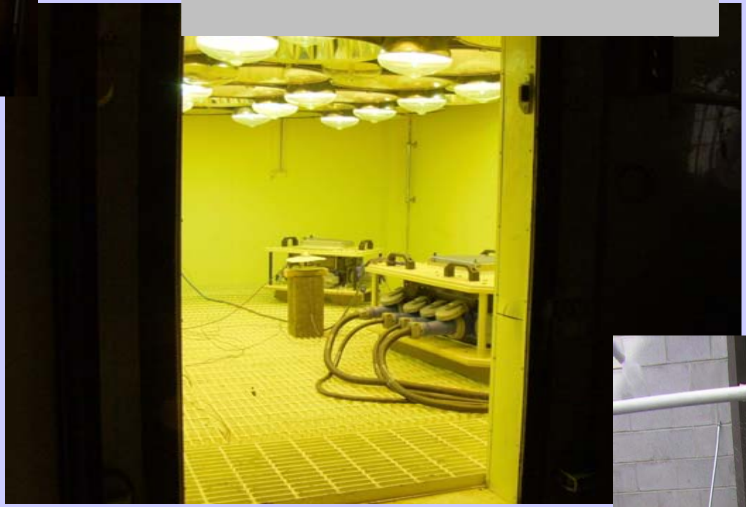
Drop testing

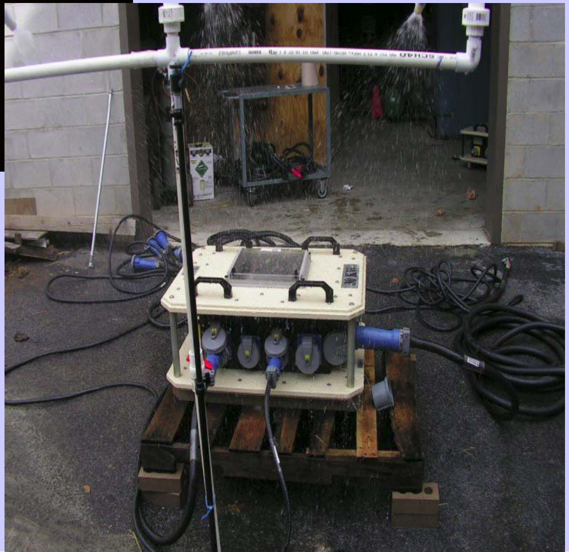
Rail Impact

Testing Transportation

Testing Environmental

DEPARTMENT OF THE NAVY UNITED STATES MARINE CORPS



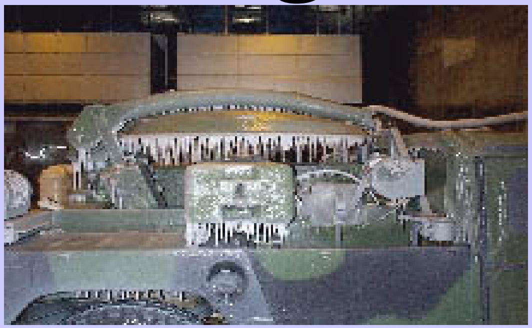


Temperature -40 to 160 F storage

-25 to 130F operating with solar

Salt Fog Rain and Humidity Dust and Sand

Testing Environmental

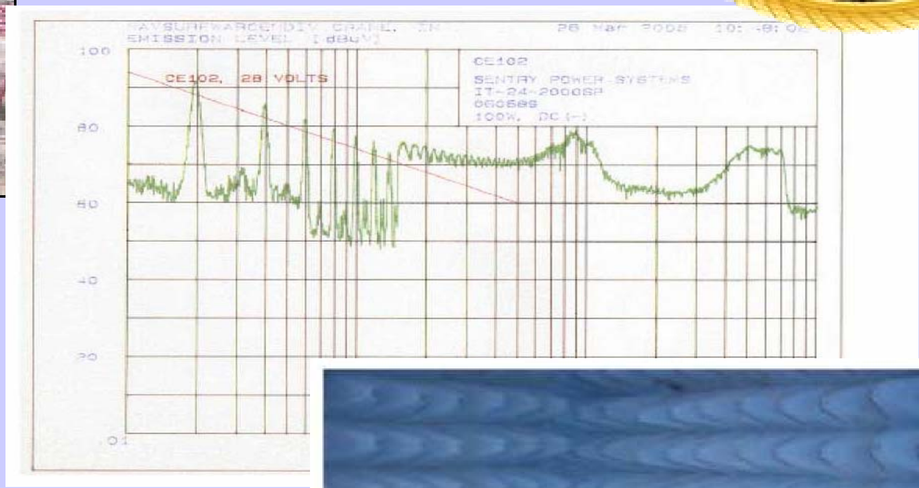


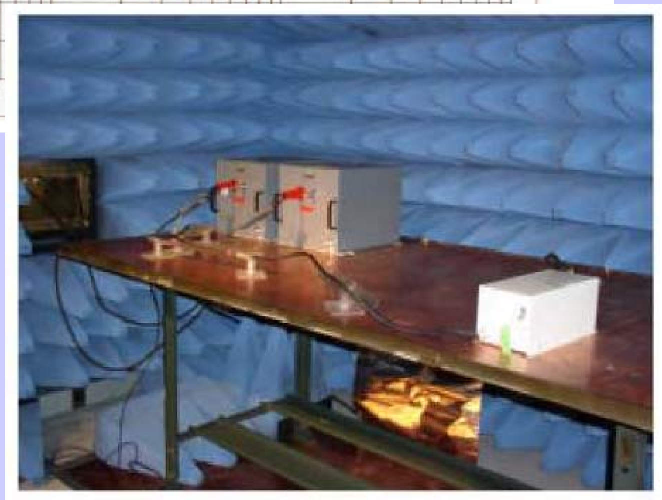
Temperature -40 to 160 F storage

-25 to 130F operating with solar

Salt Fog Rain and Humidity Dust and Sand

Testing EMI





Do I effect other equipment ?

Does other Equipment Effect Me?

Testing Performance

- **How will unit work in USMC environment does performance change?**
- **Does it perform as manufacturer claims?**
- **What are the safety issues ?**
- **Human Factors Is it Marine proof?**
- **Operational Testing with training module and manual evaluation**

Sample Power Supply Performance Test Plan

2. The following tests and examinations were performed:

Visual	Visual	Visual	Visual
*Initial Electrical	*Initial Electrical	*Initial Electrical	Initial Electrical
Drift	*Drift	Drift	Drift
*Temperature		*Temperature	*Temperature
Humidity		Humidity	
Thermal Shock		Thermal Shock	
Altitude		Altitude	
Vibration		Vibration	
Shock		Shock	
Transit Drop		Transit Drop	
Bench Handling		Bench Handling	
Dripproof		Drippoof	
*EMI		*EMI	
Salt Fog		Salt Fog	
*Post Electrical		Post Electrical	Post Electrical
Safety		Safety	
Human Factors		Human Factors	

Testing Conclusion

- **How will unit work in USMC environment?**
- **Will arrive intact?**
- **What are the limits of operation ?**
- **Is it Marine proof?**

COTS/NDI Navy Capabilities

NSWC Crane Division

Power Systems Division

Overview

Presented By:
Sue Waggoner
Electronics Engineer
Power Systems Division
NSWC Crane Division
25 April 2007

Definitions

COTS/NDI

– **Batteries currently in production and commercially available**

– **Expanded definition – chemistries available commercially with modification potential for form, fit and function to military application**

Future Challenges

- Smaller
- Lighter
- More capacity
- Last longer
- Cheaper
- Safer
- Greener

Electrochemistries

Battery Types

Alkaline (Sealed/Vented)

Aluminum-Oxygen (Air)
Cadmium-Oxygen (Air)
Carbon-Zinc
Mercury-Cadmium
Mercury-Zinc
Nickel-Zinc
Nickel-Iron
Nickel-Cadmium
Nickel-Hydrogen
Nickel-Metal Hydride
Silver-Zinc
Silver-Cadmium
Silver-Hydrogen
Silver-Metal Hydride
Silver-Iron
Zinc-Manganese Dioxide
Zinc-Oxygen (Air)

Lithium (Reserve/Active)

Carbon Monofluoride
Copper (II) Oxide
Copper Sulfide
Iodine
Manganese Dioxide
Iron Disulfide
Oxyhalide
Polymer
Sulfur Dioxide
Sulfuryl Chloride
Thionyl Chloride
Vanadium Pentoxide
Polymer Electrolyte
Cobalt Oxide
Manganese Oxide

Lithium (Rechargeable)

Lithium-Ion
Lithium-Polymer
Lithium Alloy

Thermal

Calcium/Calcium Chromate
Calcium/Potassium Di chromate
Lithium Iron/Iron Disulfide
Lithium Aluminum/Iron Disulfide
Lithium Silicon/Iron Disulfide
Lithium Silicon/Cobalt Disulfide
Magnesium/Vanadium Pentoxide

Lead-Acid

Absorbed Electrolyte
Antimony Grid
Calcium Grid
Gel Electrolyte
Flooded Electrolyte
Pure Lead Grid

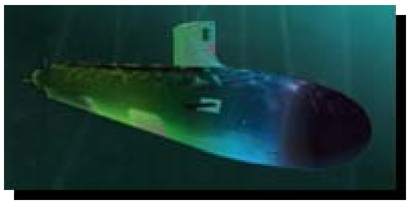
Other

PEM Fuel Cell
Seawater
Ammonium
Sodium-Sulfur

Capacity Ranges: 0.03 to 10,000 Ah

Power Systems Are Mission Driven

Submarines



Lead-Acid

VRLA

Ships

Lead-Acid

Fuel Cells

Weapons

Ag/Zn

Thermal

Ambient LI

Aircraft

Lead-Acid

NiCd

NiMh

Li-Ion

Space Apps

NiCd

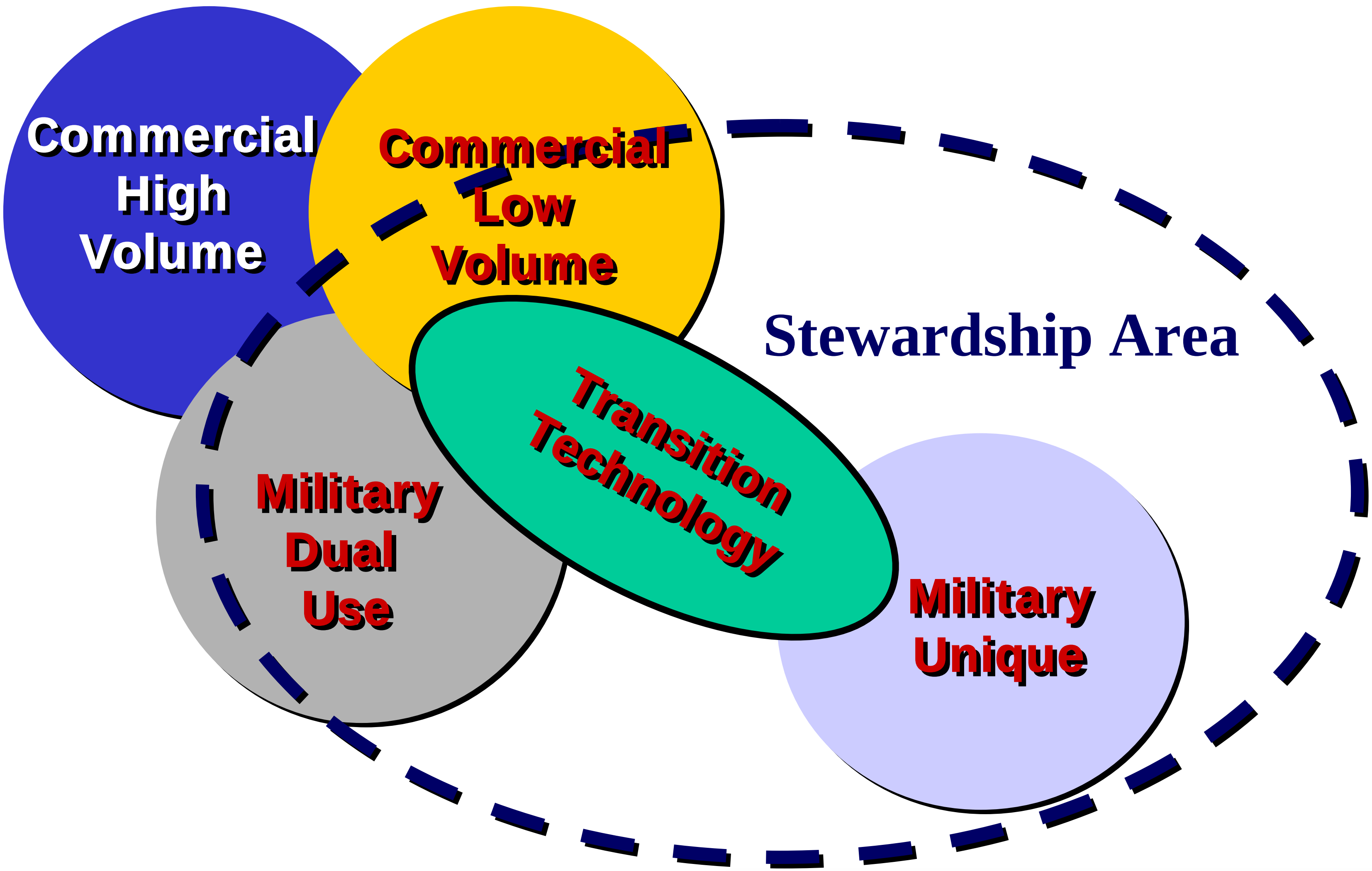
NiMh

NiH

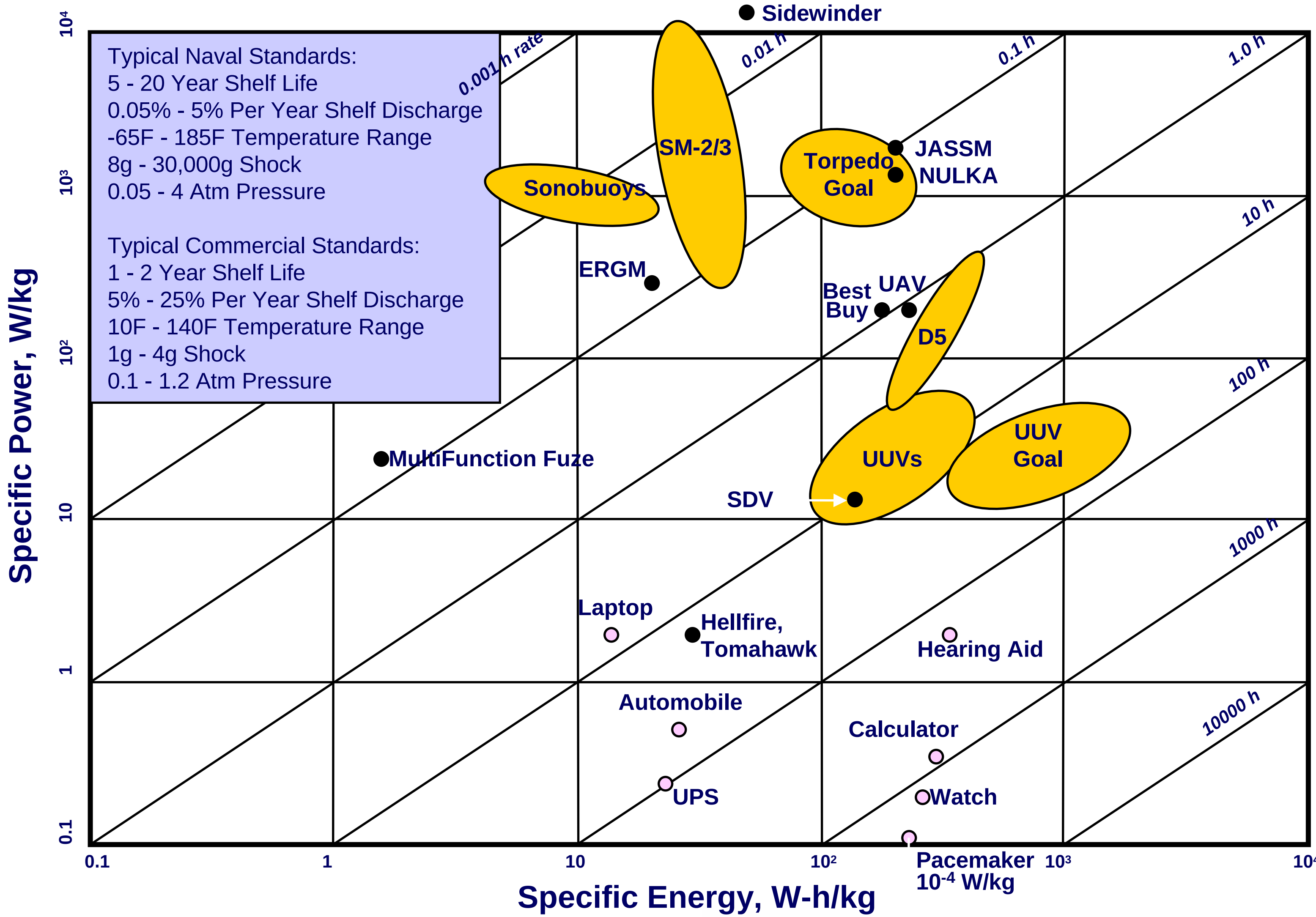
Li-Ion

Progressing Technology

Our Focus Areas



Commercial Vs Naval Batteries



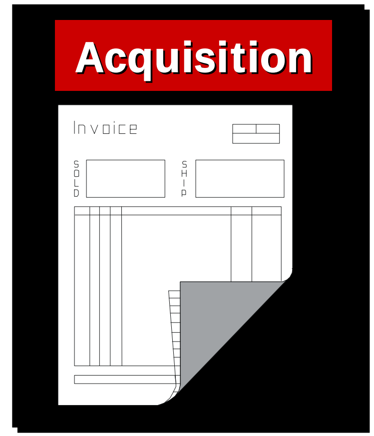
How Do They Compare?

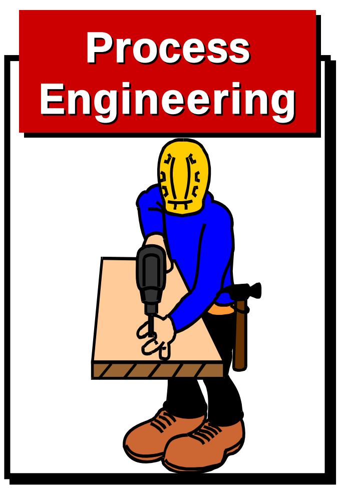
- **Typical Naval Standards:**
  - 5 - 20 Year Shelf Life
  - 0.05% - 5% Per Year Shelf Discharge
  - -65F - 185F Temperature Range
  - 8g - 30,000g Shock
  - 0.05 - 4 Atm Pressure

- **Typical Commercial Standards:**
  - 1 - 2 Year Shelf Life
  - 5% - 25% Per Year Shelf Discharge
  - 10F - 140F Temperature Range
  - 1g - 4g Shock
  - 0.1 - 1.2 Atm Pressure

Battery Involvement

Development to Disposal





Power Systems Division

PRODUCTS

- Batteries
- Fuel Cells
- Supercapacitors
- Battery Chargers & UPS
- Power Supplies

PROCESSES

- Applied Research
- Design
- Systems Engineering
- System Selection
- Acquisition Engineering
- Contract Administration
- Development
- Prototyping & Limited Mfg
- Standardization
- Test & Evaluation
- Acquisition
- Safety Certification
- Technology Evaluation/Insertion
- Production Engineering
- In-Service Engineering
- Failure Analysis
- Repair & Maintenance
- Demilitarization & System Retirement

Value Added

- Technology transition
- Established government industry team
- Knowledge brokers
- Acquisition/smart buyer support
- Production engineering
- Independent evaluation/oversight
- Test and evaluation
- Failure analysis
- Total Ownership Cost reduction

Dedicated DoD Power Systems Resources

- **Professional workforce with a unique depth of battery experience**
  - Approximately 100 govt/industry employees dedicated to the development and acquisition of power systems
  - Programs for a wide range of sponsors supporting subsurface to aerospace applications

- **Over 150,000 sq ft full spectrum power systems facilities**
  - Includes newly dedicated (Fall 2005) MILCON and unique High Energy Test Facility

- **Over $50M state-of-the-art T&E equipment**
  - Additional leveraging capability, allowing access to wide range of material/failure analysis equipment/facilities

Facilities

- **The Electrochemistry Engineering Facility (67,000 sq ft) is a state-of-the-art building for evaluation of battery technology**

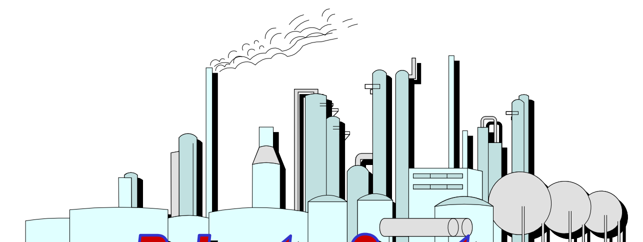
- **The facility includes : a dissection lab with a dry room, a prototyping lab, a fabrication lab, a small battery lab, and a power supply lab.**
- **Five environmental test cells**
  - **Hazardous/toxic waste collection and treatment system.**
  - **Integrated ventilation system**
  - **Physical isolated flooring (vibration systems)**
  - **Acoustical isolated walls/ceilings (vibration systems)**
  - **Reinforced walls & separation barrier (centrifuge)**
- **Integrated test control room**
- **Dry Room (3% RH)**
- **Asset Temperature Control and Conditioning Room (40º F)**

SPECIALIZING IN BATTERIES, FUEL CELLS, POWER SUPPLIES AND CHARGERS

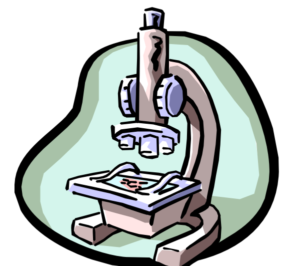
Facilities

- **The High Energy Test Facility contains 10 test cells**
  - **Data acquisition, video, other sensing equipment**
  - **Capable of containing the energy released during abuse testing of high energy batteries (Up to 10 lbs TNT equivalent)**
  - **Environmental conditioning (centrifuge, shock, vibration, altitude, temperature, etc.)**
  - **Air scrubbing system in each test cell**
- **Over 90,000 sq ft of laboratory/office space**

Who We Work With

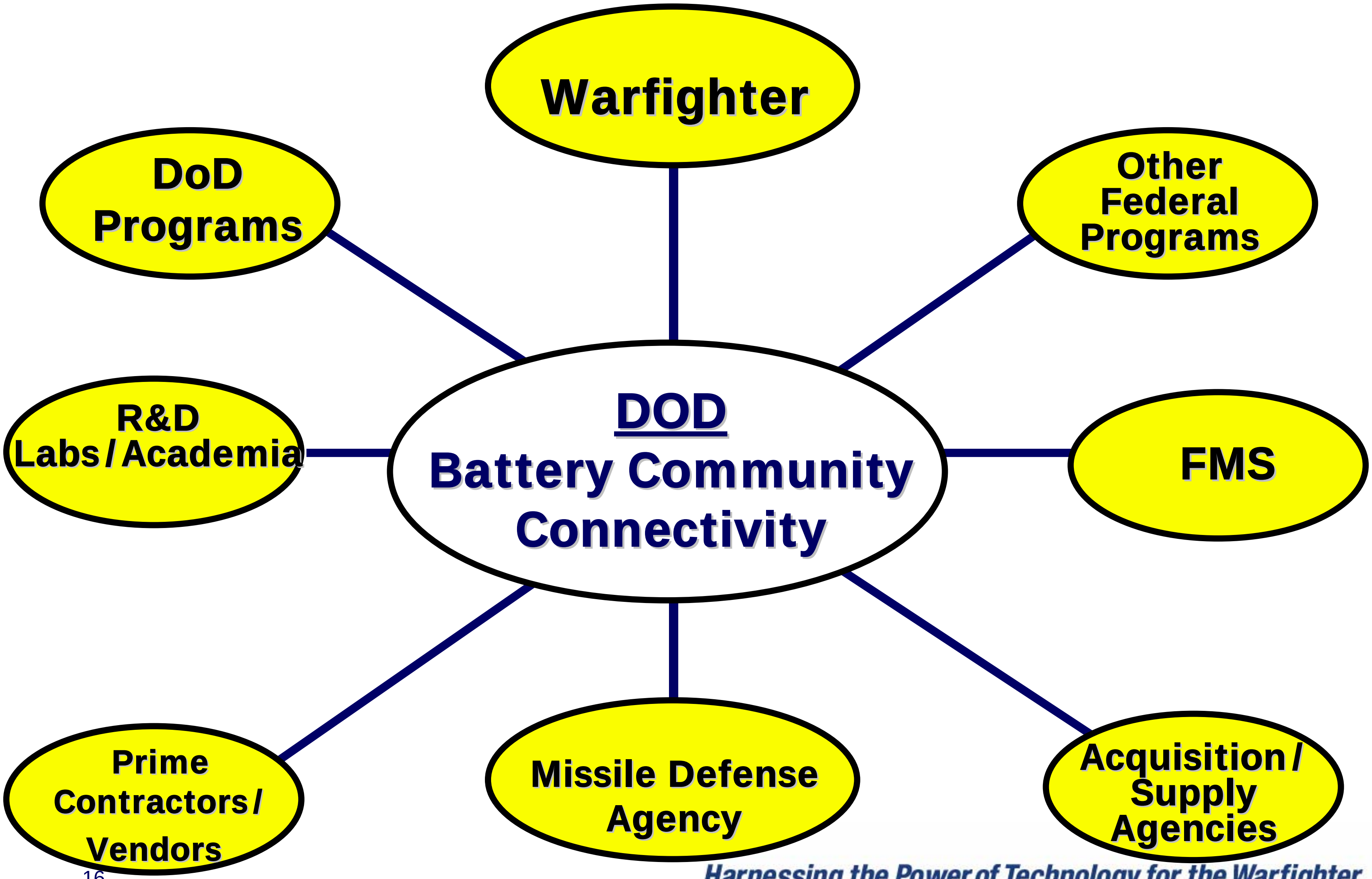


Private Sector



Academia

Networking For Greatest Benefit



Formal Charters

- ***Lead Maintenance Technology Center***
  - **Electrochemical Systems (NAVAIR)**
- ***Technical Direction Agent (TDA)***
  - **Standard Missile Batteries (NAVSEA)**
  - **Special Warfare Batteries (WARCOM)**
  - **AN/WSN-2, 2A & 5 System Batteries**
- ***In-Service Engineering Agent (ISEA)***
  - **Swimmer Delivery Vehicle Battery**
  - **Submarine and Submersible Main Storage Batteries (NAVSEA)**
  - **Seal Delivery Vehicle Automated Battery Charger (WARCOM)**
  - **Advanced Seal Delivery System Battery**
- ***Qualifying Agent***
  - **Trident, Seawolf & New Attack (Virginia Class) Submarine Battery**
- ***Overhaul Point***
  - **AN/WSN-5 & 7 Batteries (NAVICP)**

Formal Charters

- ***Co-Lead Lab***
  - Lithium Battery Safety Certification (NAVSEA)

- ***MOU***
  - Weapon System Batteries (US Army Missile Command)
  - Electrochemical Power Sources (NSWC Carderock)

- ***MOA***
  - AVBATTSS (Army Aviation, NAVAIR, NAVSUP, Air Force, Marine Corps Research, Development & Acquisition Command, NASA, Air Force Logistics Command on Aviation)
  - Submarine and Submersible Main Storage Battery Life Cycle Mgmt
  - Co-Chair, Submarine Main Storage Battery Steering Committee
  - Engineering Support to DSCR, such as Development, Testing, Qualification, & Specification Maintenance of Power Systems

- ***Acquisition Engineering Agent***
  - Submarine and Submersible Main Storage Batteries (NAVSEA)

Examples of Collaboration

<u>Navy/Army/Air Force/Maine Corps/MDA</u> – Power Technical Working Group - Navy Principal

<u>Crane/Carderock/Panama City</u> – MK 141 Battery Design and Prototyping

<u>Crane/PHNSY</u> – MSRA and Fleet Support

<u>Crane/Sperry</u> – Partnership on WSN-7 PBL

<u>Crane/NOSSA</u> – Quality Evaluation Agent for STANDARD Missile, Rolling Airframe (RAM), HARM, Sidewinder, Sparrow, NULKA

<u>Crane/Carderock</u> – ADS, PRC-149, Lithium Battery Safety Program

<u>Crane/Indian Head/China Lake</u> – Naval Energetics Enterprise

<u>Crane/Carderock NUWC</u> - Fuel Cell Steering Committee

<u>Academia/Private Sector</u> – Various Cooperative Research and Evaluation agreements and Congressional Plus-Up Programs

<u>MOU</u>

- **Weapon System Batteries (US Army Missile Comman**
- **Electrochemical Power Sources (NSWC Carderock)**
- **Acquisition Engineering (DSCR)**

US ARMY COMBINED ARMS SUPPORT COMMAND
Materiel Systems Directorate

Onboard Vehicle Power:
Talking Points on Emerging Requirements

2007 Joint Service Power Expo

25 April 2007

TIMOTHY RANEY
The Balding Engineer Guy with Glasses, MTC Technologies, Inc.

Approved for Release by:

Fort Lee Public Affairs Office, Ms. Sharon Mulligan, 2 April 2007.

Overview

- Background.
- Onboard Vehicle Power (OBVP).
- Military Hybrid-Electric Vehicles.
- Summary.

Background

- OBVP installed on about 100 HMMWVs in Army / USMC Units:
  - 3rd Corps Support Command and 82nd Airborne Division (~2000).
  - 22nd Marine Expeditionary Unit (2005).
- Limited Operational & Technical Evaluations:
  - OBVP Concept Experimentation Program, CASCOM & ATEC 1998.
  - Final Report, CASCOM – May 2001.
  - PM LTV limited technical & safety testing - Sep. 2003.
  - Positive industry efforts - results may not apply to military environment.
  - DoD PM MEP Export Power Specification (MEP-STD-001) – 2003.
  - TACOM issued Ground Precautionary Message to Units – Dec. 2003.
  - USMC PM EPS Market Surveys & Onboard Power IPT - 2002-2004.
  - USMC OBVP [small] program – 2004.
  - TARDEC & CERDEC [PGB] Technical Evaluations - 2004-2005.
  - CASCOM Tactical Wheeled Vehicle On-Board Power Study -2005-2006.
  - USMC OBVP [medium & large] programs – 2005 – 2007 (ongoing).

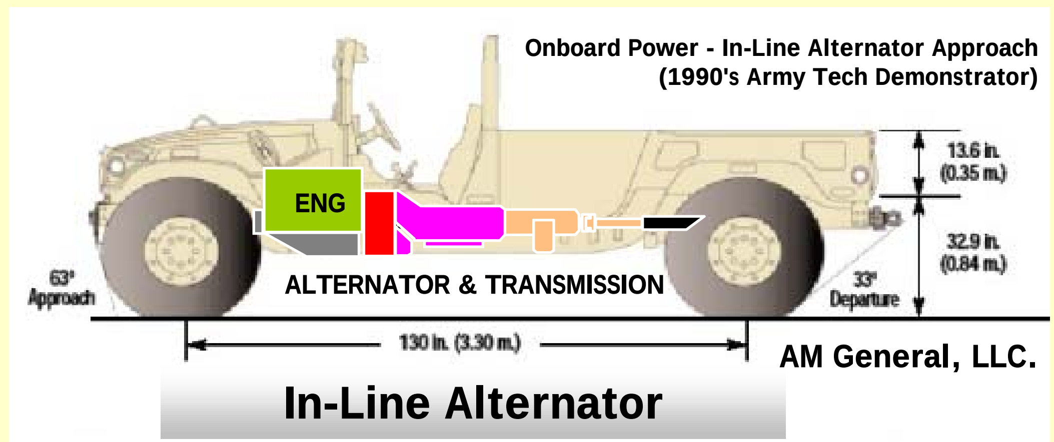
OBVP Overview

Onboard Vehicle Power

Exports AC power from an integral onboard power source to <u>external applications</u>. The underlying operational capability is "exporting tactical electric power". Output power has ranged to 20kW.

General Technical Approaches:

- **Belt-driven alternator.**
- **Shaft-driven alternator.**
- **Hydraulic-driven alternator.**



OBVP Overview

Technical & Operational Investigations.

USMC is investigating technical solutions and the US Army has studied the operational need. The intent is to identify technical approaches & mission applications where OBVP can provide an operational advantage.

OBVP Overview

Applications.

OBVP for tactical wheeled vehicles (TWV), developed for military environments, could power external applications throughout the Services & other Government agencies. They could export power to command & control (C2) systems much the same as conventional gensets. However, OBVP is generally limited to relatively short periods of operation compared to Tactical Quiet Generators (TQGs).

OBVP Mission Criteria

- **Use when unit must minimize space needs aboard aircraft or watercraft.**
- **Use when powered equipment is on or near TWV.**
- **Use if TWV & supported systems never operate independently.**
- **Use when mission-critical equipment needs back-up power.**
- **Use as auxiliary power for onboard systems when on-the-move.**
- **Unit must consider temporary loss of mobility given METT-T*.**

* **METT-T:** mission, enemy, terrain, troops available & time available

OBVP Design Criteria

Design must encompass user needs –

- Export Power - MEP-STD-001.
- Power quality - MIL-STD-1332B.
- Minimize fuel consumption increases.
- Minimize onboard weight and space claims.
- Endure severe operational & climatic environments.
- No adverse affect on host vehicle reliability & maintainability.
- OBVP should minimally affect cargo capacity or towing capabilities.

Sample Applications for OBVP

- Power for maintenance & construction (power tools).

- Charging individual Soldier equipment batteries.

- Power-on-the-move for C2 - niche now filled by 5kW &10kW auxiliary power units - APUs.

- Powering isolated company-level Command Posts for 2 to 3 days (scenario dependent).

- Onboard power for weapons, IED-defeat & targeting systems.

- Floodlights at security check-points.

10kW Output Range

Sample Applications for OBVP

- Power for tactical unmanned aerial systems (UAS) support equipment.
- Early entry forces, when high speed mobility is essential & cannot tow gensets.
- Back-up power for Command Posts, Tactical Operations Centers (TOCs) & other activities.
- Emergency power for equipment supported by 3kW to 10kW TQGs.
- Provide power to teams, patrols, convoys, during unexpected delays.
- Power for movement control teams-lights, communications, battery charging.

OBVP Operational Benefits & Drawbacks

Benefits

- Power flexibility for onboard & off-board applications
- Backup power for critical systems
- Provides power where it's unavailable
- Another power option for combatant commander
- Eliminates towed genset when that's a mission need
- Least complex to implement as a kit
- Good general purpose power option until gensets become available

Drawbacks

- TWV becomes a stationary genset
- Increased fuel needs (~30%)*
- Engine wet-stacking likely
- Space claims & increased weight
- Loss of cargo space on genset trailer
- Scheduled maintenance conflict – engine hours or mileage; now both
- Added engine wear & potentially reduced system reliability

One Example

* If operated according to the Tactical Electric Power Operational Mode Summary / Mission Profile (OMS/MP)

10kW OBVP HMMWV vs. TQG Fuel Costs

- **Fuel costs - 10kW TQG[1]** (300 hrs = peacetime genset fleet average).
  - 0.97 gal/hr X 300 hrs = 291 gals.
  - Fuel cost[2] = $15.30/gal X 291 gals = <u>$4452.00</u>
- **Fuel costs - HMMWV (with 10kW OBVP alternator):**
  - 1.4 gal/hr X 300 hrs = 420 gals.
  - Fuel cost[2] = $15.30/gal X 420 gals = <u>$6426.00</u>

~44% more fuel used

1. DoD PM MEP Handbook-Standard Family of MEP Generating Sources, 2002.

2. Fuel cost = $15.30 per gallon, FY07 DESC-subsidized cost of $2.30 per gallon for JP-8 and $13.00 per gallon for handling. Fuel handling data extracted from "More Capable Warfighting through Reduced Fuel Burden", DoD Science Board Study, January 2001.

OBVP Study Conclusions

- 10kW OBVP recommended for ~7% of light/medium TWV fleet based on mission needs.

- 10kW OBVP system would meet most unit needs (many applications under 10kW).

- Key operational benefit is back-up power for mission-critical systems.

- OBVP will not reduce trailer needs; they have additional uses (cargo).

- OBVP can supplement, but would not eliminate conventional generator sets.

- OBVP can provide power where it's unavailable now.

OBVP Study Conclusions

- **10kW OBVP increased operating costs (fuel) are significant if employment matches TEP OMS/MP.**

- **OBVP can augment vehicle power for platforms with more weapons & other onboard systems.**

- **Most likely OBVP uses include augmentation, backup & setup/teardown at operational sites.**

- **Mitigating the truck vs. genset functional conflicts within units can be significant.**

Potential Power Generation Capability for selected TWVs in Army Fleet

Tactical Hybrid Electric Vehicles

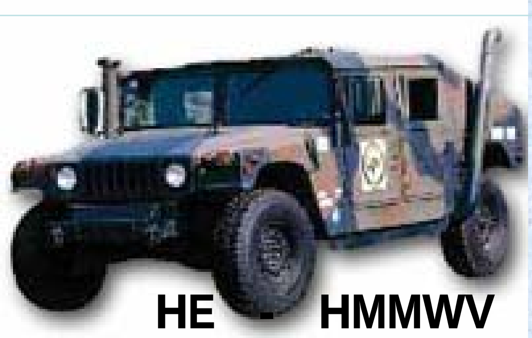
(HEV)

≠

Many thanks to Mr. Bob Crow, Mr. Rob Roche (AMSAA) & Dr. Jim Cross, RDECOM.

Tactical H E Vs

Why haven't we fielded them yet?



Component-level progress:

- **Power Electronics.**
- **Batteries.**
- **Motors.**

System Progress?

~$100M invested in HEV programs since 1995.

Many HEV components developed: motors, alternators, controls, improved semiconductors, cooling systems, etc.

Many of the basic components are almost ready to go.

But…

Two primary issues are preventing successful design and demonstration of military HEVs:

- Development of military vehicle driving cycles.
- Suitable energy storage media for a military environment.

Examples of Drive Cycle Data

- **Drive cycle data collection acquires detailed time-sampled information on how Army TWVs are actually used.**
- **Designers use this data for systems analysis & design, e.g., design of military HEV propulsion batteries**
- **Before HEVs (no energy storage), driving cycles were not as important as they are now.**

HEV propulsion battery design & life depends greatly on how the vehicle is used.

Inputs

Examples of Drive Cycle Data

Inputs

Mission Inputs:

- Vehicle speed & acceleration.
- Throttle position.
- Brake pedal apply force.
- Steering control position.
- Mission equipment electrical loads (radios, turret, etc.)

Environmental Inputs:

- Terrain Types.
- Primary & secondary roads.
- Cross-country (soil composition).
- Terrain slope.
- Terrain roughness.
- Ambient temperature.
- Crew-compartment temperature.

Drive Cycle Data

- **The Army needs to develop driving cycles that are scientifically based on vehicle usage in a tactical environment (real data from field operations).**

- **Accurate & well-defined driving cycles are essential to military HEV propulsion battery design.**

- **Without driving cycle data, poor battery design results in a vehicle that fails to achieve expected HEV benefits.**

Drive Cycle Data

Driving cycle development begins with –

- **Instrumenting vehicle fleet & collect usage data.**
- **Statistical analysis then defines vehicle performance & becomes input for simulations.**
- **Designers use these simulations to model electrical loads during HEV system development.**

Result =

Efficient HEV Design
That Meets User Needs.

Energy Storage

Efforts are on-going to develop large format, energy dense batteries for HEV propulsion.

Technical issues still remain:

- **Energy density, charge & discharge cycles.**
- **Cell-balancing, power vs. energy density trade-offs.**
- **Operating at temperature extremes and safety.**

Example: Each cell must have almost identical characteristics; having essentially the same internal resistance is critical.

Energy Storage

Other Technical issues...

- Weak cells can become an electrical load and/or reduce energy content & degrade output.

- Safety – lower resistance or shorted cells can become hotter & can ignite; many existing electrolytes are flammable & lithium electrodes can be very reactive.

- Better quality control, electronic cell-balancing, cell conditioning techniques & modular battery assemblies will help resolve these issues (more work is needed).

- Existing battery candidates are not suitable for military systems that experience severe climatic extremes.

- High temps accelerate self-discharge rates & complicate thermal management. Low temps reduce battery output.

Energy Storage

- Charge management, thermal, weight & space claim issues much greater vs. commercial HEVs.
- Military systems are much heavier
- Shock & vibration more extreme.
- Military temperatures are more extreme.

Energy Storage Issues

- Must have consistent battery chemical 'mix' (batch-to-batch & year-to-year).
- Must have consistent plate material, spacing & thickness.
- Same internal resistance for all cells (most desirable).
- Need rigorous process control & Acceptance Testing.

HEV Summary

- Technical issues - significant R&D needed for military HEV propulsion batteries.
- Scientifically based MILITARY driving cycles are needed…. Data from a tactical environment.
- Propulsion battery design relies on having accurate & detailed driving cycles.
- Without operationally derived driving cycles, vendor fuel economy claims cannot be verified.
- If the battery is undersized for the load, reliability & life suffers.
- Battery life & reliability are dramatically affected by how it is used & misused.

Tactical Electric Power Team

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Acting Deputy Project Manager - Mobile Electric Power.

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Product Manager - Small Power Sources, APUs & Power Distro.

LTC John Kelleher USA - john.kelleher@us.army.mil
Product Manager - Medium & Large Power Sources.

www.cascom.lee.army.mil *www.pm-mep.army.mil*

References

MEP-STD-001, General Specification, Export Power-Vehicle Mounted (to 30kW), DoD Project Manager - Mobile Electric Power, 5 May 2004.

Onboard Power White Paper, Timothy Raney, MTC Technologies, Inc., for DoD Project Manager - Mobile Electric Power, 8 September 2005.

Tactical Electric Power Operational Requirements Document, CARDS# 16125, 11 August 2004.

MIL-STD-1332B, Definitions of Tactical, Prime, Precise and Utility Terminology for Classification of the DoD Mobile Electric Generators, 13 March 1973 (reactivated 10 July 2001).

DoD Directive# 4120-11, Standardization of Mobile Electric Power Generating Sources, 9 July 1993.

MIL-STD-1275B, Characteristics of 28V DC Electrical Systems in Military Vehicles, US Army Tank-Automotive & Armaments Command, 20 November 1997.

MIL-STD 461-E, Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems & Equipment, 20 August 1999.

MIL-STD-705C, Generator Sets, Engine-Driven, Methods of Tests & Instructions, 24 April 1989.

MIL-STD-1474D, Noise Limits for Army Material, 12 February 1997.

Army Regulation 700-101, Joint Operating Procedures Management and Standardization of Mobile Electric Power Generating Sources, 29 November 1999.

DoD Military Handbook-633F (Draft), Standard Family of Mobile Electric Power Generating Sources: General Description Information & Characteristics Data Sheets, May 2001.

Questions?

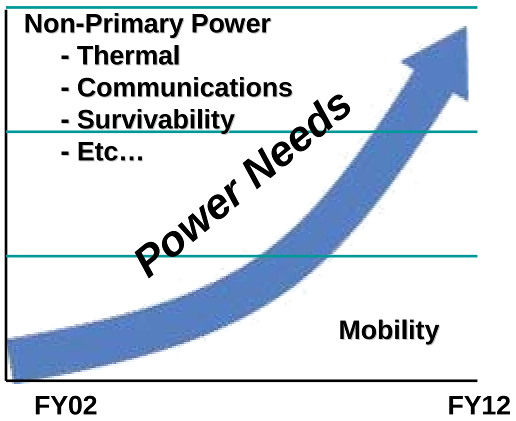
Thank You for Your Attention!

Joint Light Tactical Vehicle Power Requirements

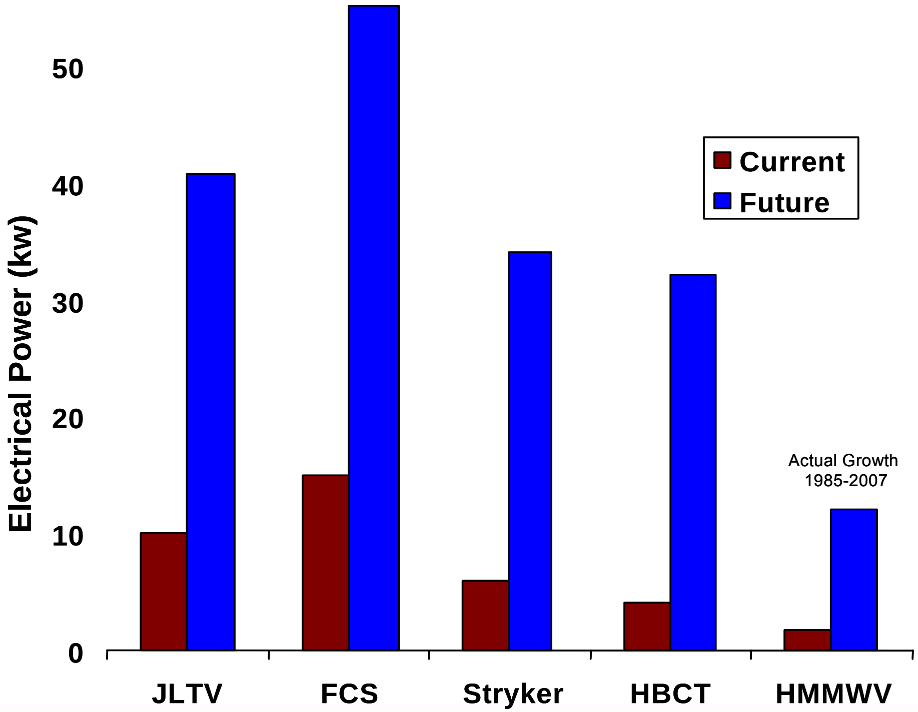
DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited

Ms. Jennifer Hitchcock
Associate Director of
Ground Vehicle Power and Mobility

Ground Vehicle Power and Energy



Non-Primary Power
Estimated Electrical Power Growth



JLTV Vehicle Categories – Force Application

Mission Role Variants

Combat Tactical Vehicle – Provide support for maneuver forces (infantry and combat arms)

- Infantry Fire Team Carrier
- Heavy Guns Carrier
- Anti-tank Missile Carrier

Power Estimates

Mobility + On Board + Exportable ~ 335-400HP

On Board Requirement – 7kW(t) 10kW(o)*

Exportable Requirement – 10Kw(t) 30kW(o)*

Silent Watch – 2 hours (t) 6 hour (o)*
(includes 2 SINCGARS, Blue Force Tracker, Remote weapon System)

* Stated in JLTV RFI Dec. 06, Attachment 2a

On Board and Export Power must be provided while vehicle is mobile or stationary

JLTV Vehicle Categories – Focused Logistics

Mission Role Variants

- Provide support for combat support and combat service support forces
- Utility Vehicle Light
- Utility Vehicle Heavy
- Shelter Carrier
- Ground Mobility Vehicle

Power Estimates

Mobility + On Board + Exportable ~335-400HP

On Board Requirement – 7kW(t) 10kW(o)*

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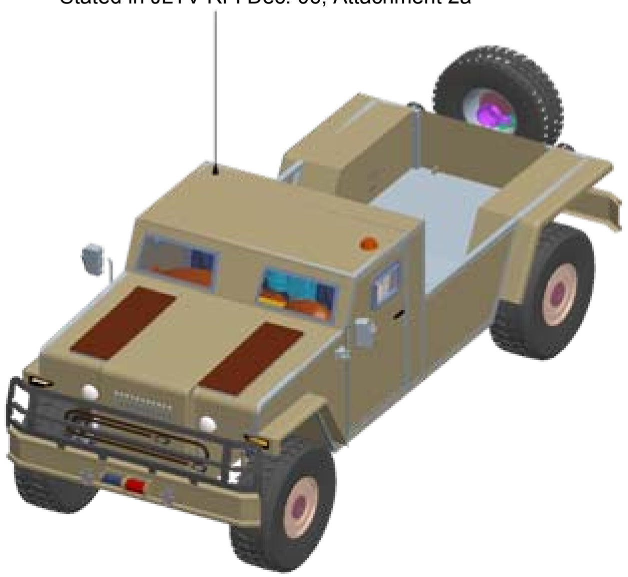

On Board and Export Power must be provided while vehicle is mobile or stationary

JLTV Vehicle Categories – Battlespace Awareness

Mission Role Variant

Long Range Surveillance

Provide support for conventional force long range surveillance, Special Operations Command, plus other Service reconnaissance and surveillance forces conducting intelligence, surveillance and reconnaissance missions.

General Purpose

C2

Power Estimates

Mobility + On Board + Exportable ~280-320HP

On Board Requirement – 10kW(t) 14kW(o)*

Exportable Requirement – 10Kw(t) 30kW(o)*

Silent Watch – 4 hours (t) 12 hour (o)*

(includes 2 SINCGARS, Blue Force Tracker, Remote weapon System and Long Range Acquisition Sensor)

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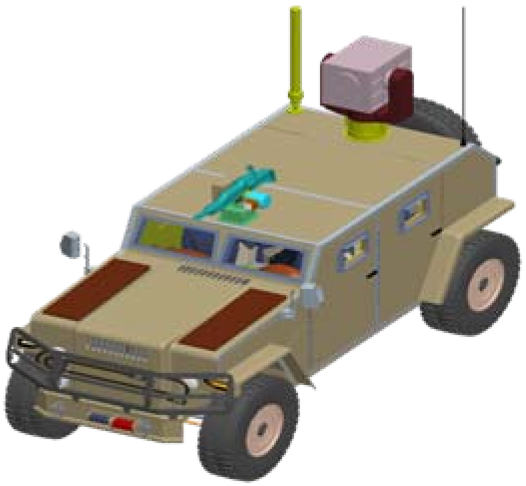
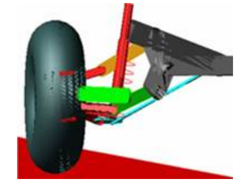


On Board and Export Power must be provided while vehicle is mobile or stationary

Requirements - Functional Decomposition

Non Primary Power



Advanced Suspension

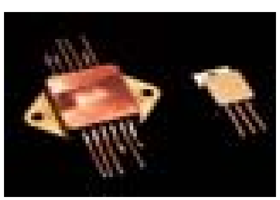
Ground Vehicle Power and Energy

- **Prime Power**
  - **Engine**
    - Diesel
    - Turbine
    - Gasoline
    - Stratified Charge
  - **Drivetrain**
    - Electrical
    - Mechanical
    - Driveline Components
    - Mobility Components
- **Non Primary Power**
  - Diesel
  - Turbine
  - Fuel Cell
  - Battery
  - Generators
- **Energy Storage**
  - Batteries
  - Capacitors
  - Flywheels
  - Fuels
- **Power & Thermal Management**
  - **Power Management**
    - Power Generation
    - Energy Storage
    - Power/Thermal Control & Distribution
  - **Thermal Management**
    - Power Plant Cooling
    - Power-Electronics Cooling
    - Climate Control

JP8 Reformer

Militarized Commercial Engines

Hybrid Components



Energy Storage

Power Dense Quiet Power Generation

Back-up

Armor Holdings (AH) – FTTS Demonstrator
Maneuver Sustainment Vehicle (MSV) & Companion Trailer (CT)

Survivability & Force Protection
■ Monocoque cab
■ Modular Armor Kit
■ Front, rear and side cameras
■ NBC system
■ Collision avoidance
■ 2 person cab
Network Centricity
■ Integrated communications suite
■ Integrated computer system
Sustainability
■ 30 kW exportable AC power
■ Enhanced On-board Diagnostics
■ Lube for Life (bushings & bearings)
Transportability
■ 96"w x 102"h x 406"l
■ C-17 transportable
■ 49,000 lbs. Curb Weight
■ 75,000 lbs. Gross Vehicle Weight
Mobility
■ Parallel Hybrid Electric Propulsion
■ Air Suspension Height Control (ASHC) and Load Monitoring System (LMS)
■ Central Tire Inflation System (CTIS) / run-flat
■ Anti-Lock Braking System (ABS)
Payload
■ 13 Tons - Residual Payload w / B Kit
Distribution
■ Multi-functional LHS & MHE crane hook lift and a forklift
■ 6,100 lbs at 23 feet MHE
■ 13,200 lbs at 24' 3" LHS
Operational Range
■ 300 miles

■ C9 8.4L engine (335 kW @ 2200 rpm)
■ 4 NIMH batteries 8.5 amp hrs, 336 Volts
■ Integrated starter/generator (ISG) 120kW peak, 100 kW continuous
■ 7 speed hydrokinetic automatic transmission

MSV Companion Trailer (CT)

Commonality with MSV
■ Axles, suspension, wheels, tires, brakes, ABS, Central Tire Inflation System (CTIS), 24 Volt CAN/Bus System
Distribution
■ Receives Flat Racks and ISO containers from Truck Load Handling System (LHS)
■ Move loads and trailer without truck
Mobility
■ 3 Axle with semi-autonomous operation
■ Steering on Axle #1 and #3
■ Turning radius (Autonomous): 20 ft-8 in
■ Max speed 1.89 MPH
■ Vertical Obstacle 24 in Step
■ Gradient (Autonomous) – 30%
■ Air Bag Independent Wishbone Suspension with ride height control
■ 230 mm Jounce, 200mm Rebound
■ Central Tire Inflation System (CTIS)
Deployability
■ Self-Powered offload C-130 and operational watercraft Joint Requirement
Operational Range
■ Range 65 miles
■ Power Diesel Engine (73 HP)
■ Hydrostatic Drive Train
■ Tethered Coupled / Wireless Uncoupled Control

Survivability & Force Protection
- Monocoque cab
- Modular Armor Kit
- 2 person cab

Network Centricity
- Integrated communications suite
- Integrated computer system

Sustainability
- Limited on-board diagnostics
- 75kW integrated, exportable AC power

Transportability
- 92” w x 83” h x 221” l
- CH-47 and C-130 Transportable
- Demonstrator curbweight = 18,600 lbs
- Reducible weight = 16,400 lbs

Mobility
- Parallel Hybrid electric propulsion
- Torsion bar suspension, passive shocks
- Designed for adjustable ride height control
- Central Tire Inflation Systems (CTIS)
- Rear axle steer
- Anti-Lock Braking System (ABS)

Payload
- 3400 lb payload with integral armor
- On-board crane with 800 lb lift @ 8’

Operational Range
- Over 555 mile range

UV Companion Trailer

Commonality with UV
- Common tires, suspension, brakes with truck

Payload
- 5500 lb payload

Survivability & Force Protection
■ Monocoque cab
■ Modular Armor Kit
■ Machine Gun Ringmount
■ 2 crew + 1 jump seat

Network Centricity
■ Integrated communications suite
■ Integrated computer system

Sustainability
■ Limited on-board diagnostics
■ 8kW integrated exportable AC power

Transportability
■ 95" w x 90" h x 229" l
■ CH-47 & C-130 Transportable
■ Demonstrator curbweight = 21,600 lb
■ Reducible curbweight = 19,705 lb

Mobility
■ Parallel Hybrid electric propulsion
■ SLA suspension with Air Spring, passive shocks
■ Adjustable Ride height control (4 position)
■ Central Tire Inflation (CTIS)
■ Anti-Lock Braking System (ABS)

Payload
■ 3300 lb payload with A-kit armor
■ On-board crane with 1000 lb lift @ 5'

Operational Range
■ 528 mile range

UV Companion Trailer

Commonality with UV
■ Common tires, suspension, brakes with truck

Payload
■ 6100 lb payload

On-Board Vehicle Power

Joint Service Power Exposition
25 April 2007

Session 12

Introduction

Mr. Michael Gallagher, USMC

Urgent Requirements

Dr. Jim Cross, Army

Emerging Requirements

Mr. Tim Raney, Army

Legacy Systems

Mr. Michael Gallagher, USMC

Future Systems

Joint Light Tactical Vehicle

Jennifer Hitchcock, Army

Future Combat System

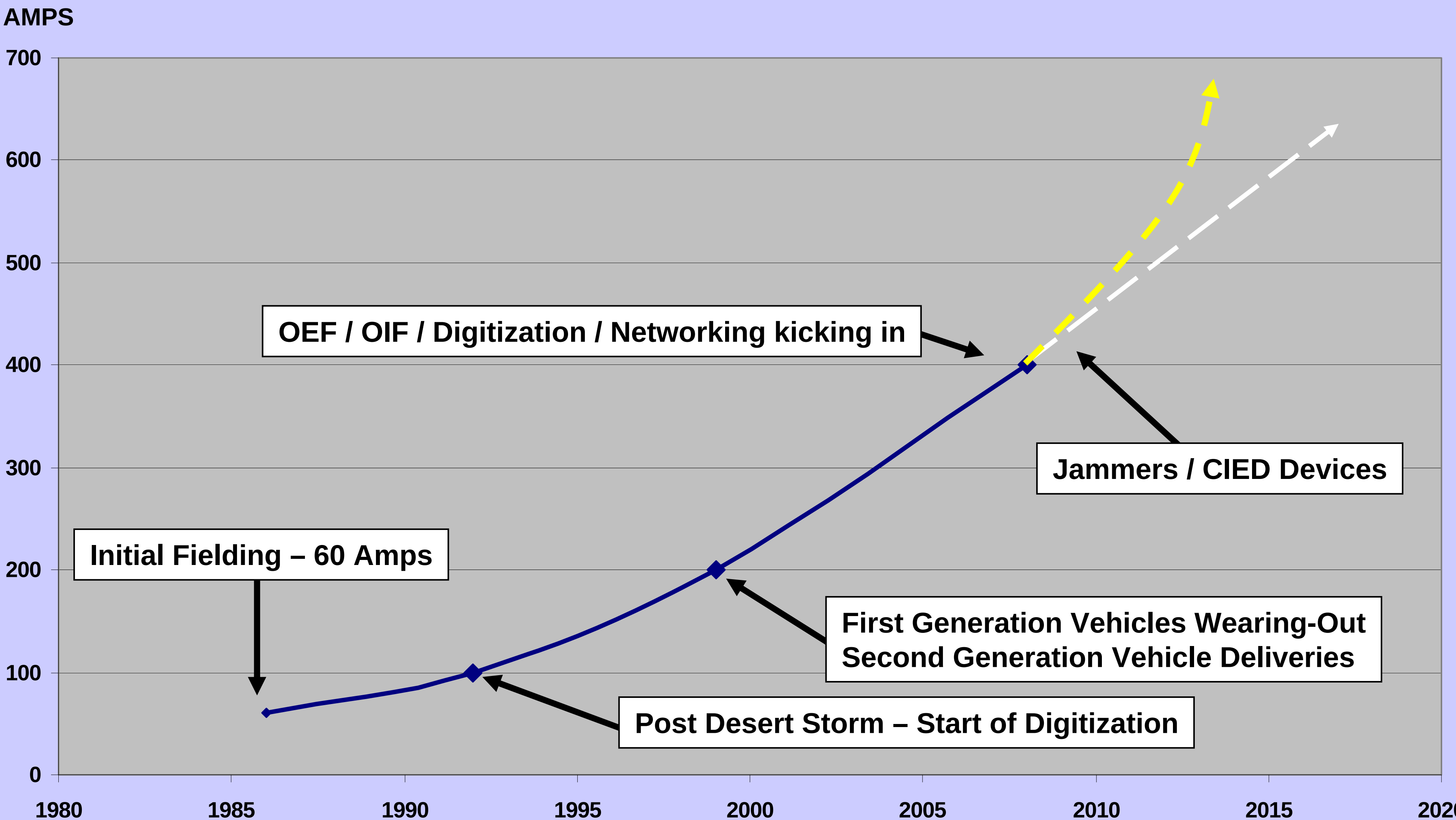
Mr. Francis Rush, Army

Session 14

In <u>no</u> order of preference

• William Henrickson	E-power
• Nadr Nasr	Oshkosh Truck Co
• Stephen Cortese	BAE Systems
• Tom Trzaska	General Dynamics

Alternator Amperage Rating on HMMWV at 28 VDC



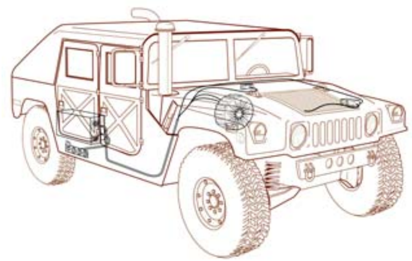
Marine Corps
On-Board Vehicle Power Systems for Legacy Military Vehicles

Joint Service Power Exposition
2007

On-Board Vehicle Power Systems

DC-AC Power Inverters
1500- 3000 watts

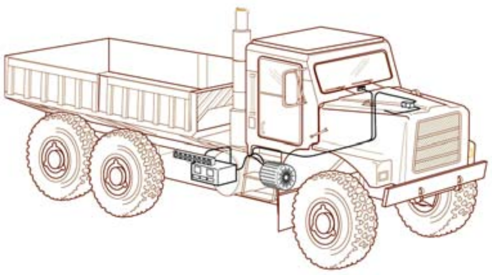
OBVP - Medium
30 kW Add-on HMMWV



Retrofits for
In-Theater Assets

OBVP - Small
5 – 8 kW (HMMWV)

OBVP - Large
120 kW (MTVR)



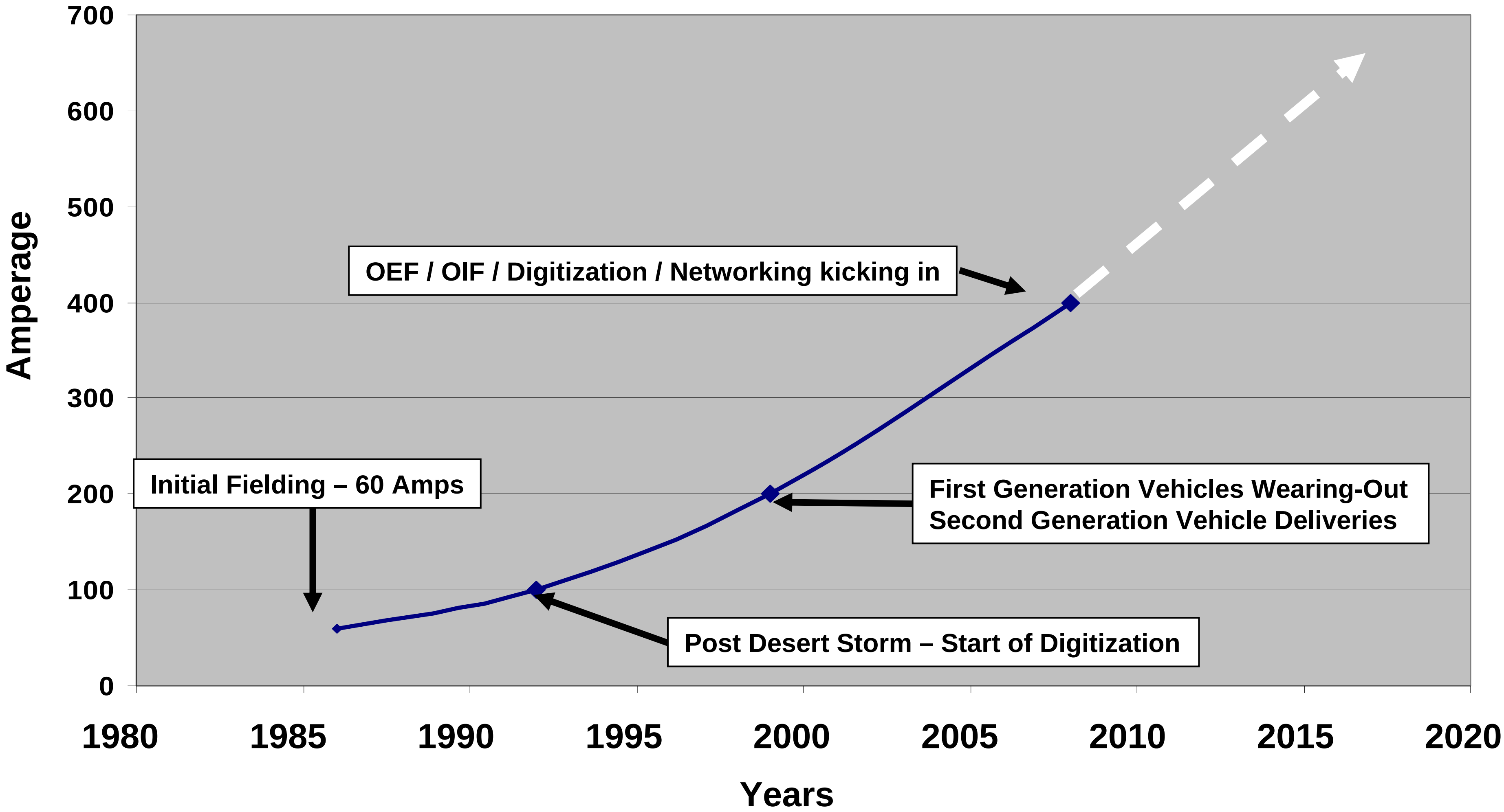
Vehicle Power Inverters

- Requirement for DC-AC Power Inverter
  - 18-32 VDC input
  - 120 VAC, single phase output
  - 1800 watts minimum output
  - Easily installed
  - Readily available / commercial based item
- Market Research and testing conducted
- GSA schedule showed adequate competition
- Solicited, competed, awarded in 2007
- Multi-year contract awarded to IRIS QP-1800
  - Inverter
  - Ruggedized carrying case
  - NATO cable connector
  - 5600 articles planned

On-Board Vehicle Power - Small

- Up to 400 Amps at 28 VDC needed
- Army has lead on retrofit kit
  - Vehicles in theater
  - DC power needs
- USMC will procure kits in 2007/2008
  - M1114, M1151, M1152 configurations
- Continuing to investigate / test inverters at higher power levels for AC power needs
- Future USMC vehicles will be procured with 400 Amp capacity (LVSR, MRAP)

Alternator Amperage Rating on HMMWV at 28 VDC

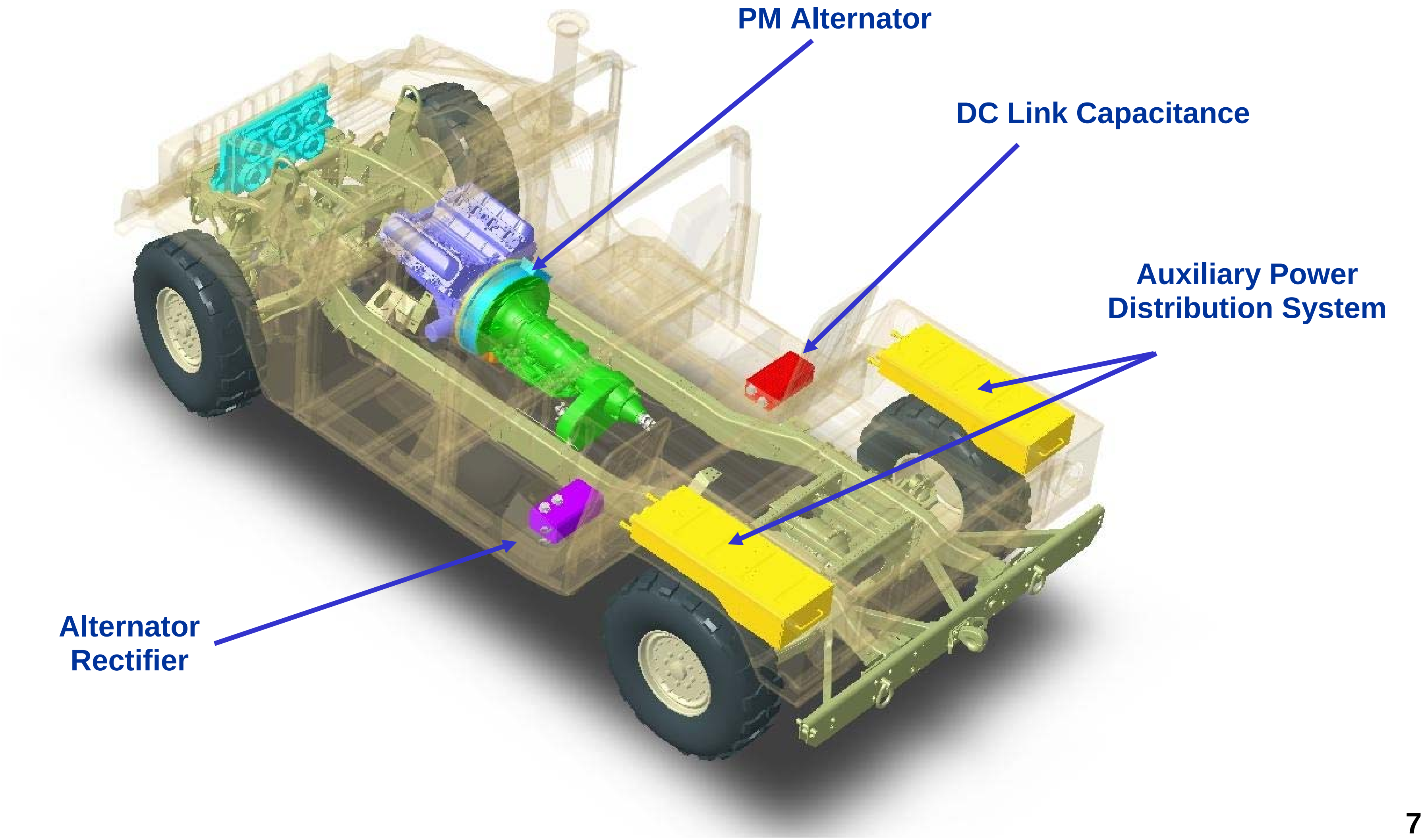


On-Board Vehicle Power
Medium & Large Systems

- **Technology Demonstrations funded by Office of Naval Research**
- **HMMWV based system:**
  - **30 kilowatts stationary / 10 kilowatts on-the-move**
  - **Will be mounted on HMMWV M1123**
  - **Power output at 120/208 VAC, 60 hz**
  - **Two vehicles can be connected in parallel (60 kW output)**
  - **Can synchronize to MEP-805B generator**
- **MTVR based system:**
  - **120 kilowatts stationary / 20 kilowatts on-the-move / 3 kW transition**
  - **Mk 23 Truck**
  - **Power output at 120/208 VAC, 60 hz**
  - **Can synchronize to MEP-807A generator**
- **Vehicles will be delivered in 2007 for evaluation**

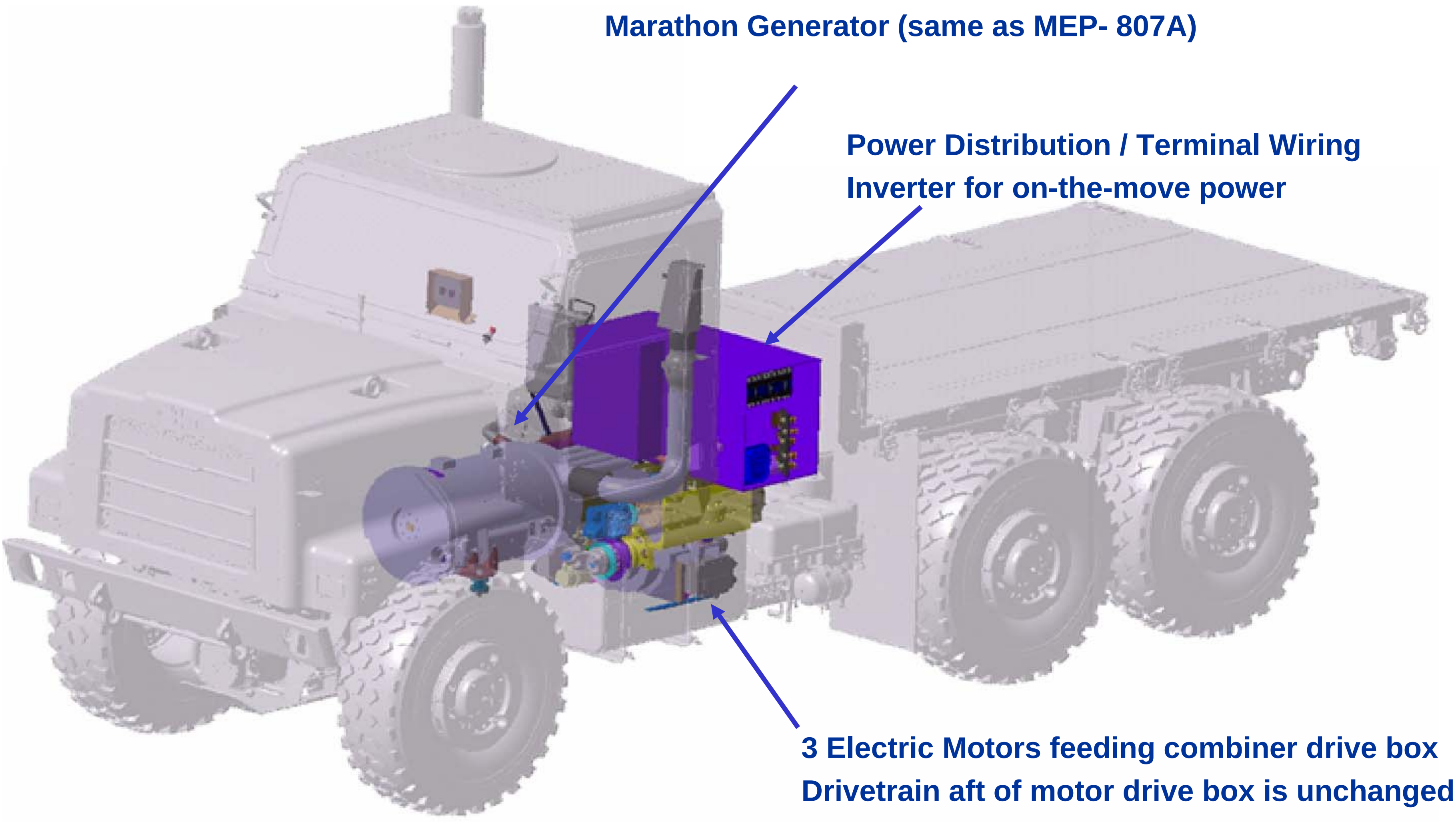
On-Board Vehicle Power - Medium

DRS Technologies Selected for Hardware Fabrication Phase

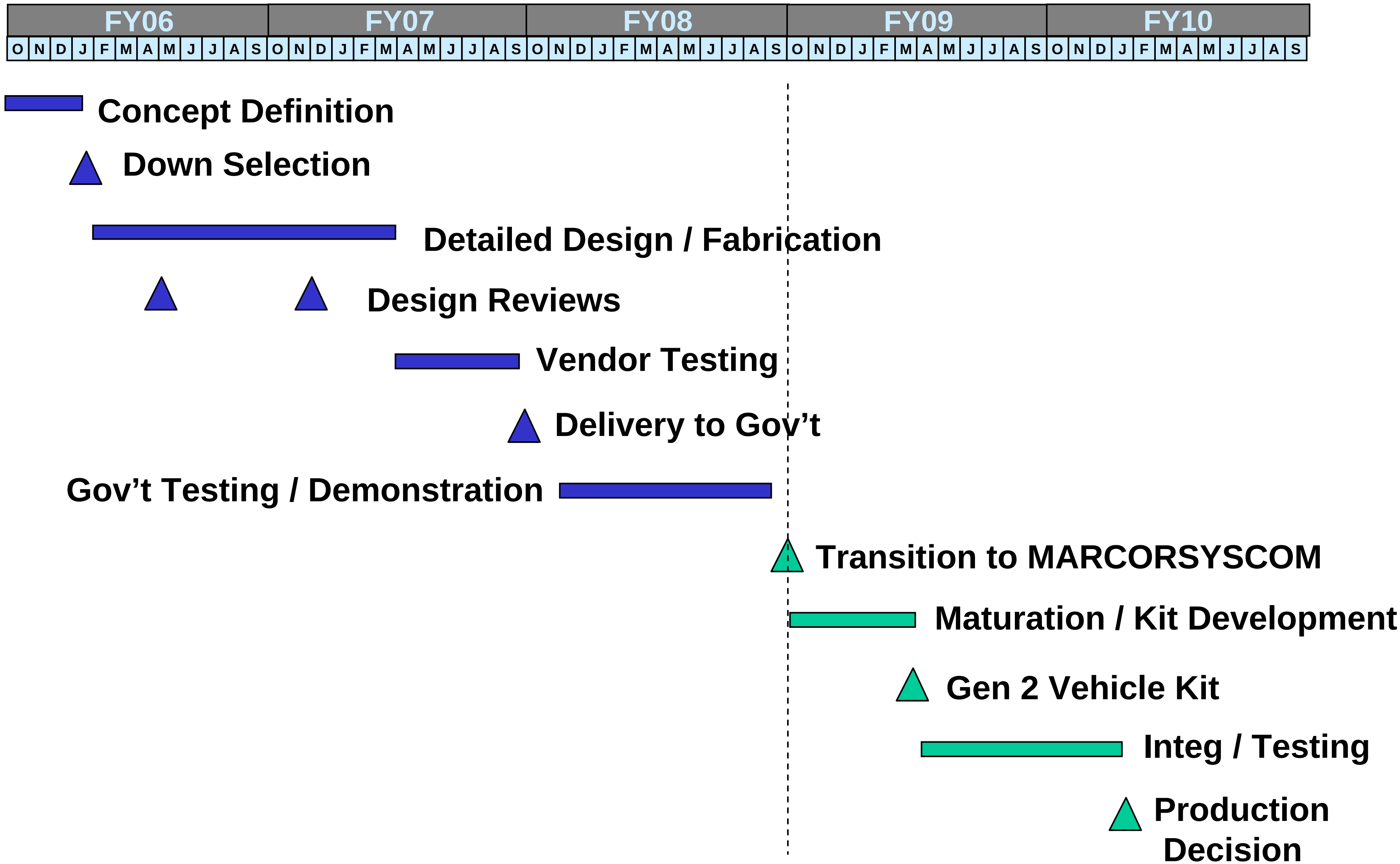


On-Board Vehicle Power - Large

OshKosh Selected for Hardware Fabrication Phase



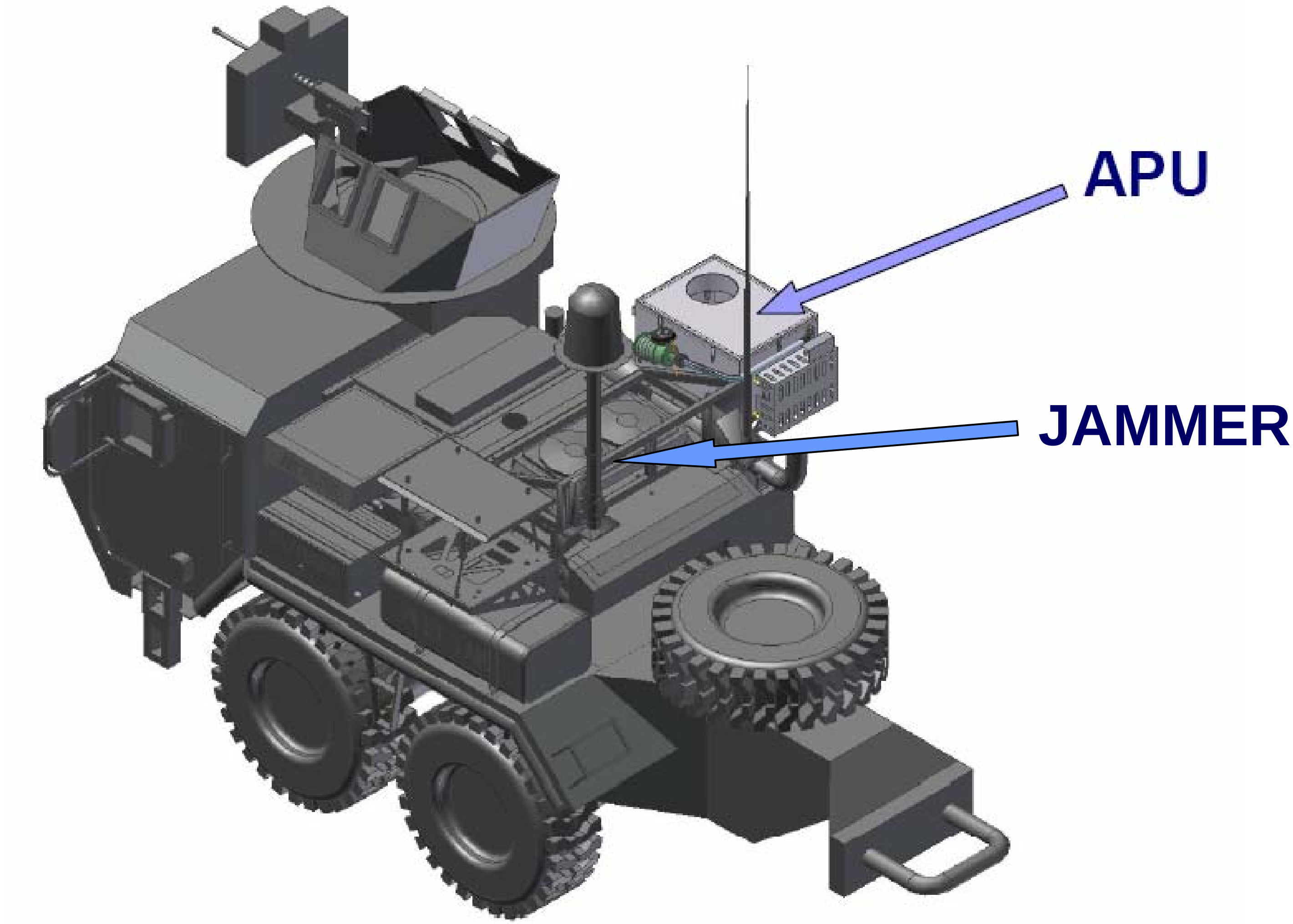
OBVP Schedule (HMMWV & MTVR)



On-Board Vehicle Power Unique Applications

- Power community continually requested to support other platforms
    - Tanks
    - Logistics Vehicle System
    - HIMARS
    - Light Armored Vehicle
    - Lightweight 155 Howitzer
    - Amphibious Assault Vehicle
    - Force Protection / Military Police
- Continued need for power for Jammers, Silent Watch, stationary applications
- Necessary when host vehicle incapable of power load, or host vehicle can not be retrofitted with larger alternator
- 28 VDC Gensets needed (various sizes, ratings, restrictions)

On-Board Vehicle Power - Unique



Watch FedBizOpps for solicitations

Joint Light Tactical Vehicle Power Requirements

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited

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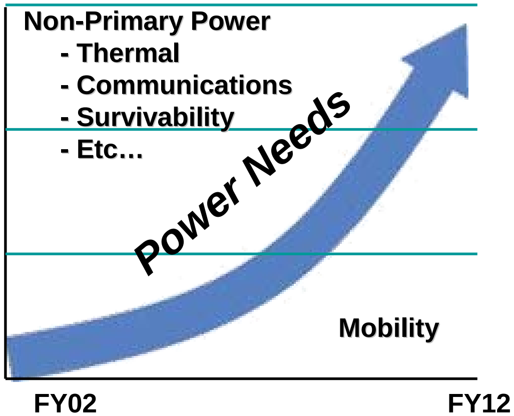
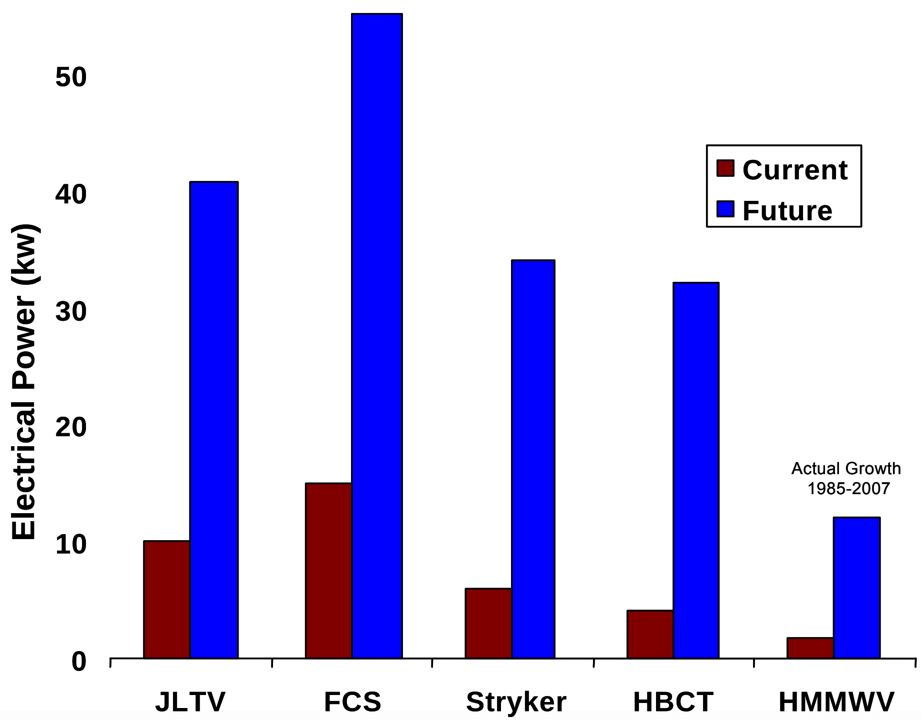
Ground Vehicle Power and Energy



Non-Primary Power
Estimated Electrical Power Growth



TARDEC

JLTV Vehicle Categories – Force Application

Mission Role Variants

Combat Tactical Vehicle – Provide support for maneuver forces (infantry and combat arms)

- Infantry Fire Team Carrier
- Heavy Guns Carrier
- Anti-tank Missile Carrier

Power Estimates

Mobility + On Board + Exportable ~ 335-400HP

On Board Requirement – 7kW(t) 10kW(o)*

Exportable Requirement – 10Kw(t) 30kW(o)*

Silent Watch – 2 hours (t) 6 hour (o)*
(includes 2 SINCGARS, Blue Force Tracker, Remote weapon System)

* Stated in JLTV RFI Dec. 06, Attachment 2a

On Board and Export Power must be provided while vehicle is mobile or stationary

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- Provide support for combat support and combat service support forces
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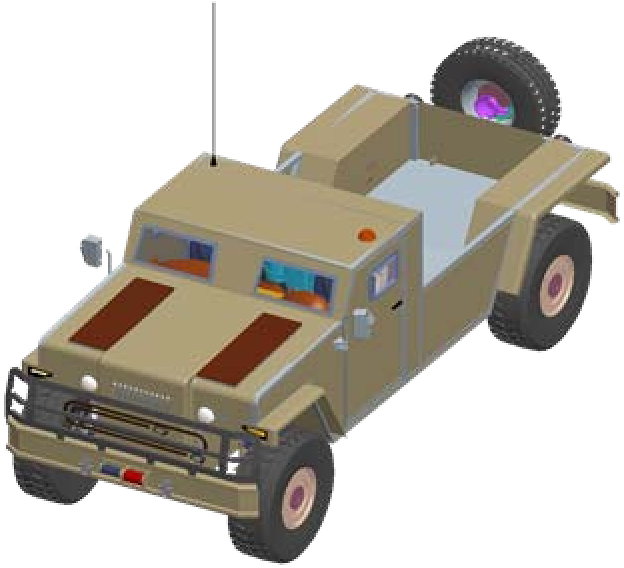

On Board and Export Power must be provided while vehicle is mobile or stationary

JLTV Vehicle Categories – Battlespace Awareness

Mission Role Variant

- **Long Range Surveillance**
  - **Provide support for conventional force long range surveillance, Special Operations Command, plus other Service reconnaissance and surveillance forces conducting intelligence, surveillance and reconnaissance missions**.
- General Purpose
- C2

Power Estimates

Mobility + On Board + Exportable ~280-320HP

On Board Requirement – 10kW(t) 14kW(o)*

Exportable Requirement – 10Kw(t) 30kW(o)*

Silent Watch – 4 hours (t) 12 hour (o)*
(includes 2 SINCGARS, Blue Force Tracker, Remote weapon System and Long Range Acquisition Sensor)

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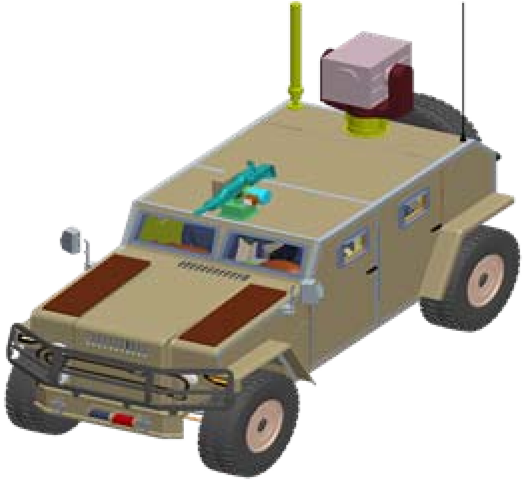

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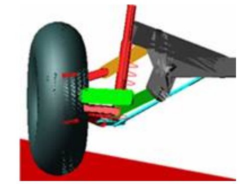
Requirements - Functional Decomposition

Non Primary Power



Advanced Suspension

- **Ground Vehicle Power and Energy**
  - **Prime Power**
    - **Engine**
      - Diesel
      - Turbine
      - Gasoline
      - Stratified Charge
    - **Drivetrain**
      - Electrical
      - Mechanical
      - Driveline Components
      - Mobility Components
  - **Non Primary Power**
    - Diesel
    - Turbine
    - Fuel Cell
    - Battery
    - Generators
  - **Energy Storage**
    - Batteries
    - Capacitors
    - Flywheels
    - Fuels
  - **Power & Thermal Management**
    - **Power Management**
      - Power Generation
      - Energy Storage
      - Power/Thermal Control & Distribution
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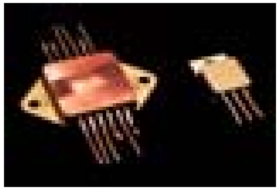
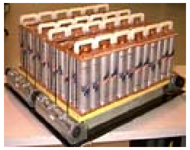
      - Power Plant Cooling
      - Power-Electronics Cooling
      - Climate Control

JP8 Reformer

Militarized Commercial Engines

Hybrid Components





Energy Storage

Power Dense Quiet Power Generation

Back-up

Armor Holdings (AH) – FTTS Demonstrator

Maneuver Sustainment Vehicle (MSV) & Companion Trailer (CT)

Survivability & Force Protection
■ Monocoque cab
■ Modular Armor Kit
■ Front, rear and side cameras
■ NBC system
■ Collision avoidance
■ 2 person cab
Network Centricity
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■ Steering on Axle #1 and #3
■ Turning radius (Autonomous): 20 ft-8 in
■ Max speed 1.89 MPH
■ Vertical Obstacle 24 in Step
■ Gradient (Autonomous) – 30%
■ Air Bag Independent Wishbone Suspension with ride height control
■ 230 mm Jounce, 200mm Rebound
■ Central Tire Inflation System (CTIS)
Deployability
■ Self-Powered offload C-130 and operational watercraft Joint Requirement
Operational Range
■ Range 65 miles
■ Power Diesel Engine (73 HP)
■ Hydrostatic Drive Train
■ Tethered Coupled / Wireless Uncoupled Control

International Military Group – FTTS Demonstrator
Utility Vehicle (UV) & Trailer

Survivability & Force Protection
■ Monocoque cab
■ Modular Armor Kit
■ 2 person cab

Network Centricity
■ Integrated communications suite
■ Integrated computer system

Sustainability
■ Limited on-board diagnostics
■ 75kW integrated, exportable AC power

Transportability
■ 92” w x 83” h x 221” l
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Mobility
■ Parallel Hybrid electric propulsion
■ Torsion bar suspension, passive shocks
■ Designed for adjustable ride height control
■ Central Tire Inflation Systems (CTIS)
■ Rear axle steer
■ Anti-Lock Braking System (ABS)

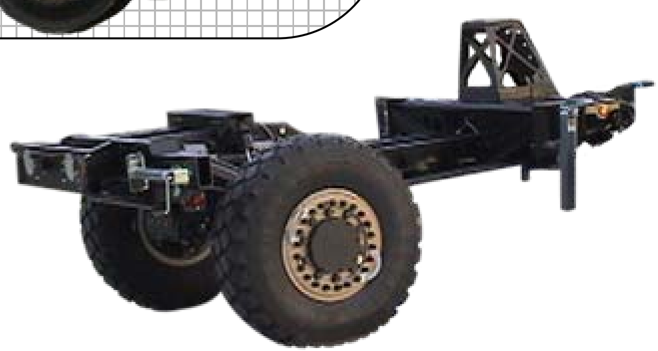
Payload
■ 3400 lb payload with integral armor
■ On-board crane with 800 lb lift @ 8’

Operational Range
■ Over 555 mile range

UV Companion Trailer

Commonality with UV
■ Common tires, suspension, brakes with truck

Payload
■ 5500 lb payload



Survivability & Force Protection
■ Monocoque cab
■ Modular Armor Kit
■ Machine Gun Ringmount
■ 2 crew + 1 jump seat

Network Centricity
■ Integrated communications suite
■ Integrated computer system

Sustainability
■ Limited on-board diagnostics
■ 8kW integrated exportable AC power

Transportability
■ 95” w x 90” h x 229” l
■ CH-47 & C-130 Transportable
■ Demonstrator curbweight = 21,600 lb
■ Reducible curbweight = 19,705 lb

Mobility
■ Parallel Hybrid electric propulsion
■ SLA suspension with Air Spring, passive shocks
■ Adjustable Ride height control (4 position)
■ Central Tire Inflation (CTIS)
■ Anti-Lock Braking System (ABS)

Payload
■ 3300 lb payload with A-kit armor
■ On-board crane with 1000 lb lift @ 5’

Operational Range
■ 528 mile range

UV Companion Trailer

Commonality with UV
■ Common tires, suspension, brakes with truck

Payload
■ 6100 lb payload

US ARMY COMBINED ARMS SUPPORT COMMAND
Materiel Systems Directorate

Onboard Vehicle Power:
Talking Points on Emerging Requirements

2007 Joint Service Power Expo

25 April 2007

TIMOTHY RANEY
The Balding Engineer Guy with Glasses, MTC Technologies, Inc.

Support Starts Here

Approved for Release by:

Fort Lee Public Affairs Office, Ms. Sharon Mulligan, 2 April 2007.

Overview

- Background.
- Onboard Vehicle Power (OBVP).
- Military Hybrid-Electric Vehicles.
- Summary.

Background

- OBVP installed on about 100 HMMWVs in Army / USMC Units:
  - 3rd Corps Support Command and 82nd Airborne Division (~2000).
  - 22nd Marine Expeditionary Unit (2005).
- Limited Operational & Technical Evaluations:
  - OBVP Concept Experimentation Program, CASCOM & ATEC 1998.
  - Final Report, CASCOM – May 2001.
  - PM LTV limited technical & safety testing - Sep. 2003.
  - Positive industry efforts - results may not apply to military environment.
  - DoD PM MEP Export Power Specification (MEP-STD-001) – 2003.
  - TACOM issued Ground Precautionary Message to Units – Dec. 2003.
  - USMC PM EPS Market Surveys & Onboard Power IPT - 2002-2004.
  - USMC OBVP [small] program – 2004.
  - TARDEC & CERDEC [PGB] Technical Evaluations - 2004-2005.
  - CASCOM Tactical Wheeled Vehicle On-Board Power Study -2005-2006.
  - USMC OBVP [medium & large] programs – 2005 – 2007 (ongoing).

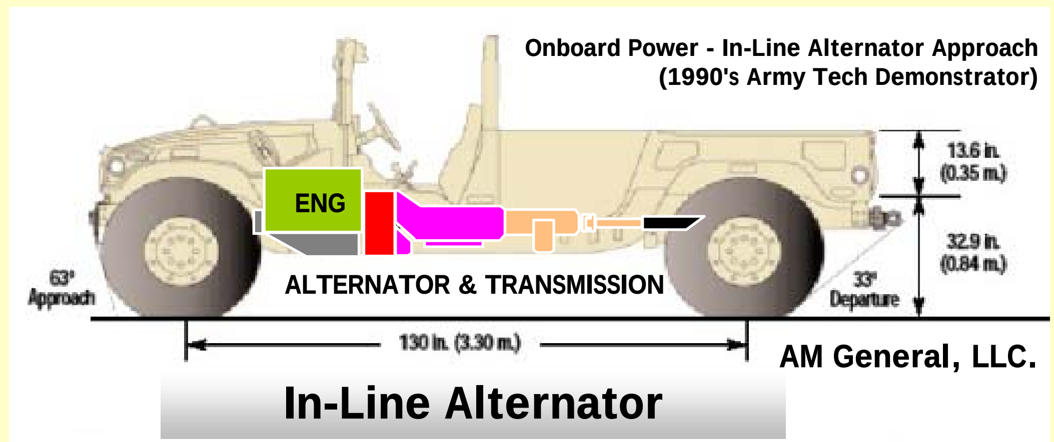
OBVP Overview

Onboard Vehicle Power

Exports AC power from an integral onboard power source to <u>external applications</u>. The underlying operational capability is "exporting tactical electric power". Output power has ranged to 20kW.

General Technical Approaches:

- **Belt-driven alternator.**
- **Shaft-driven alternator.**
- **Hydraulic-driven alternator.**



OBVP Overview

Technical & Operational Investigations.

USMC is investigating technical solutions and the US Army has studied the operational need. The intent is to identify technical approaches & mission applications where OBVP can provide an operational advantage.

OBVP Overview

Applications.

OBVP for tactical wheeled vehicles (TWV), developed for military environments, could power external applications throughout the Services & other Government agencies. They could export power to command & control (C2) systems much the same as conventional gensets. However, OBVP is generally limited to relatively short periods of operation compared to Tactical Quiet Generators (TQGs).

OBVP Mission Criteria

- Use when unit must minimize space needs aboard aircraft or watercraft.
- Use when powered equipment is on or near TWV.
- Use if TWV & supported systems never operate independently.
- Use when mission-critical equipment needs back-up power.
- Use as auxiliary power for onboard systems when on-the-move.
- Unit must consider temporary loss of mobility given METT-T*.

* **METT-T:** mission, enemy, terrain, troops available & time available

OBVP Design Criteria

Design must encompass user needs –

- Export Power - MEP-STD-001.
- Power quality - MIL-STD-1332B.
- Minimize fuel consumption increases.
- Minimize onboard weight and space claims.
- Endure severe operational & climatic environments.
- No adverse affect on host vehicle reliability & maintainability.
- OBVP should minimally affect cargo capacity or towing capabilities.

Sample Applications for OBVP

- Power for maintenance & construction (power tools).
- Charging individual Soldier equipment batteries.
- Power-on-the-move for C2 - niche now filled by 5kW &10kW auxiliary power units - APUs.
- Powering isolated company-level Command Posts for 2 to 3 days (scenario dependent).
- Onboard power for weapons, IED-defeat & targeting systems.
- Floodlights at security check-points.

10kW Output Range

Sample Applications for OBVP

- Power for tactical unmanned aerial systems (UAS) support equipment.
- Early entry forces, when high speed mobility is essential & cannot tow gensets.
- Back-up power for Command Posts, Tactical Operations Centers (TOCs) & other activities.
- Emergency power for equipment supported by 3kW to 10kW TQGs.
- Provide power to teams, patrols, convoys, during unexpected delays.
- Power for movement control teams-lights, communications, battery charging.

OBVP Operational Benefits & Drawbacks

Benefits

- Power flexibility for onboard & off-board applications
- Backup power for critical systems
- Provides power where it's unavailable
- Another power option for combatant commander
- Eliminates towed genset when that's a mission need
- Least complex to implement as a kit
- Good general purpose power option until gensets become available

Drawbacks

- TWV becomes a stationary genset
- Increased fuel needs (~30%)*
- Engine wet-stacking likely
- Space claims & increased weight
- Loss of cargo space on genset trailer
- Scheduled maintenance conflict – engine hours or mileage; now both
- Added engine wear & potentially reduced system reliability

One Example

* If operated according to the Tactical Electric Power Operational Mode Summary / Mission Profile (OMS/MP)

10kW OBVP HMMWV vs. TQG Fuel Costs

- **Fuel costs - 10kW TQG[1] (300 hrs = peacetime genset fleet average).**
  - **0.97 gal/hr X 300 hrs = 291 gals.**
  - **Fuel cost[2] = $15.30/gal X 291 gals = <u>$4452.00</u>**
- **Fuel costs - HMMWV (with 10kW OBVP alternator):**
  - **1.4 gal/hr X 300 hrs = 420 gals.**
  - **Fuel cost[2] = $15.30/gal X 420 gals = <u>$6426.00</u>**

~44% more fuel used

1. DoD PM MEP Handbook-Standard Family of MEP Generating Sources, 2002.

2. Fuel cost = $15.30 per gallon, FY07 DESC-subsidized cost of $2.30 per gallon for JP-8 and $13.00 per gallon for handling. Fuel handling data extracted from "More Capable Warfighting through Reduced Fuel Burden”, DoD Science Board Study, January 2001.

OBVP Study Conclusions

- 10kW OBVP recommended for ~7% of light/medium TWV fleet based on mission needs.

- 10kW OBVP system would meet most unit needs (many applications under 10kW).

- Key operational benefit is back-up power for mission-critical systems.

- OBVP will not reduce trailer needs; they have additional uses (cargo).

- OBVP can supplement, but would not eliminate conventional generator sets.

- OBVP can provide power where it's unavailable now.

OBVP Study Conclusions

•10kW OBVP increased operating costs (fuel) are significant if employment matches TEP OMS/MP.

• OBVP can augment vehicle power for platforms with more weapons & other onboard systems.

• Most likely OBVP uses include augmentation, backup & setup/teardown at operational sites.

• Mitigating the truck vs. genset functional conflicts within units can be significant.

Potential Power Generation Capability for selected TWVs in Army Fleet

Tactical Hybrid Electric Vehicles

(HEV)

≠

Many thanks to Mr. Bob Crow, Mr. Rob Roche (AMSAA) & Dr. Jim Cross, RDECOM.

Tactical H E Vs

Why haven't we fielded them yet?

Component-level progress:

- **Power Electronics.**
- **Batteries.**
- **Motors.**

System Progress?

~$100M invested in HEV programs since 1995.

Many HEV components developed: motors, alternators, controls, improved semiconductors, cooling systems, etc.

Many of the basic components are almost ready to go.

But…

Two primary issues are preventing successful design and demonstration of military HEVs:

- Development of military vehicle driving cycles.
- Suitable energy storage media for a military environment.

Examples of Drive Cycle Data

- **Drive cycle data collection acquires detailed time-sampled information on how Army TWVs are actually used.**
- **Designers use this data for systems analysis & design, e.g., design of military HEV propulsion batteries**
- **Before HEVs (no energy storage), driving cycles were not as important as they are now.**

HEV propulsion battery design & life depends greatly on how the vehicle is used.

Inputs

Examples of Drive Cycle Data

Inputs

Mission Inputs:

- **Vehicle speed & acceleration.**
- **Throttle position.**
- **Brake pedal apply force.**
- **Steering control position.**
- **Mission equipment electrical loads (radios, turret, etc.)**

Environmental Inputs:

- **Terrain Types.**
- **Primary & secondary roads.**
- **Cross-country (soil composition).**
- **Terrain slope.**
- **Terrain roughness.**
- **Ambient temperature.**
- **Crew-compartment temperature.**

Drive Cycle Data

- The Army needs to develop driving cycles that are scientifically based on vehicle usage in a tactical environment (real data from field operations).

- Accurate & well-defined driving cycles are essential to military HEV propulsion battery design.

- Without driving cycle data, poor battery design results in a vehicle that fails to achieve expected HEV benefits.

Drive Cycle Data

Driving cycle development begins with –

- **Instrumenting vehicle fleet & collect usage data.**
- **Statistical analysis then defines vehicle performance & becomes input for simulations.**
- **Designers use these simulations to model electrical loads during HEV system development.**

Result =

Efficient HEV Design That Meets User Needs.

Energy Storage

Efforts are on-going to develop large format, energy dense batteries for HEV propulsion.

Technical issues still remain:

- **Energy density, charge & discharge cycles.**
- **Cell-balancing, power vs. energy density trade-offs.**
- **Operating at temperature extremes and safety.**

Example: Each cell must have almost identical characteristics; having essentially the same internal resistance is critical.

Energy Storage

Other Technical issues…

- Weak cells can become an electrical load and/or reduce energy content & degrade output.

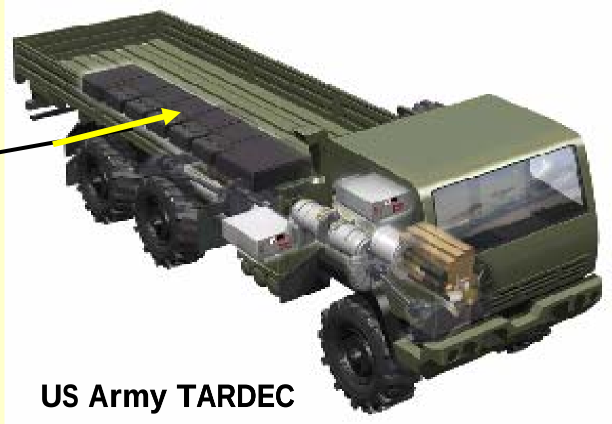
- Safety – lower resistance or shorted cells can become hotter & can ignite; many existing electrolytes are flammable & lithium electrodes can be very reactive.

- Better quality control, electronic cell-balancing, cell conditioning techniques & modular battery assemblies will help resolve these issues (more work is needed).

- Existing battery candidates are not suitable for military systems that experience severe climatic extremes.

- High temps accelerate self-discharge rates & complicate thermal management. Low temps reduce battery output.

Energy Storage



- Charge management, thermal, weight & space claim issues much greater vs. commercial HEVs.
- Military systems are much heavier
- Shock & vibration more extreme.
- Military temperatures are more extreme.

Energy Storage Issues

- Must have consistent battery chemical 'mix' (batch-to-batch & year-to-year).
- Must have consistent plate material, spacing & thickness.
- Same internal resistance for all cells (most desirable).
- Need rigorous process control & Acceptance Testing.

HEV Summary

- **Technical issues - significant R&D needed for military HEV propulsion batteries.**
- **Scientifically based MILITARY driving cycles are needed…. Data from a tactical environment.**
- **Propulsion battery design relies on having accurate & detailed driving cycles.**
- **Without operationally derived driving cycles, vendor fuel economy claims cannot be verified.**
- **If the battery is undersized for the load, reliability & life suffers.**
- **Battery life & reliability are dramatically affected by how it is used & misused.**

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www.cascom.lee.army.mil *www.pm-mep.army.mil*

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Questions?

Thank You for Your Attention!

U.S. Army
Research, Development & Engineering Command

On-Board Vehicle Power Briefing & Way Forward

25 April 2007

Power & Energy Integrated Product Team

Co-Chairs

Dr. Jim Cross, PM-MEP/CERDEC

Dr. Ed Shaffer, ARL

Mr. Tom Nguyen, RDECOM SOSI

Outline & Purpose

Purpose

Summarize results of collaborative RDECOM Power & Energy IPT assessment, recommendations, and way forward for meeting On-board Vehicle Power Needs Statement

Background

- **On Board Vehicle Power JUONS, 17 Jul 06**
- JRAC agreement to support, O/A 7 Sep 06
- P&E IPT initial assessment, 12 Sep 06
- Briefing to JIEDDO, 5 Oct 06 (updated 6 Oct 06)
- CERDEC Power Assessment, Sep – Oct 06
- COS IPT Face-to-Face, 18 Oct 06
- MG Nadeau and COL (P) Dellarocco briefing, 19 Oct 06
- JRAB Pre-Brief, 9 Nov 06
- AR2B (Army Resources and Requirements Board) – validates reqms
- **JRAC Briefing / Decision, 16 Nov 06**

Bottom Line Up Front

- IPT conducted detailed technical analysis and power assessment versus JUONS nominal requirements
- JIEDDO PIR defeat systems represent major contributor to power requirements
- On-going and future vehicle power programs do not address urgent/immediate need for legacy fleet
- **Recommended Approach**:

HMMWV (M1114)

- **Technical Approach:**
  - 400A Niehoff MIL-STD alternator using enhanced pulley
  - Include 150-400W DC/AC inverter with convenience outlets
  - If increased power required above 60A (e.g., to meet CREWS future spirals) add Automatic Throttle Control in production kits
- **Cost:** $0.86M for initial integration, testing/safety qualification, fielding and operational user assessment of 15 integration kits
- **Schedule:**
  - 120 days from approval to delivery of kits in theater
  - 165 days to operational assessment; procurement approval
  - TBD days to first production kit deliveries

RG-31

- **Technical Approach:**

  Consider two approaches - evaluate on risk and component availability.
  - **ALT 1: Immediate Requirement:** 280A Niehoff alternator (MIL-STD, on Stryker) using enhanced pulley and high idle; include 150-400W DC/AC inverter convenience outlets
  - **ALT 2: Potential Spiral Improvement:** 400A Alternator (e.g. Fisher A5/60, Niehoff, other), coupled to AC/DC converter; include 150-400W DC/AC inverter convenience outlets
- **Cost:**
  - **ALT 1:** $0.55M for initial integration, testing/safety qualification, fielding and operational user assessment of 5 integration kits
  - **ALT 2:** $1.08M for initial integration, testing/safety qualification, fielding and operational user assessment of 5 integration kits
- **Schedule (ALT 1 only)**
  - 120 days from approval to delivery of kits in theater
  - 165 days to operational assessment; procurement approval
  - TBD days to first production kit deliveries

- REF and CERDEC conducting real world power assessment in theater – 60 day effort

Need Statement

System Definition and Power Requirements

- **Operate Following Systems**
  - Communications Equipment - SINCGARS
  - Blue Force Tracker (BFT)
  - IED Defeat Equipment
    - Rhino
    - Blowtorch
    - Electra
    - Dragon Spike
  - Common Remote Operating Weapon System (CROWS)
  - Counter Radio-control- IED Electronic Warfare system (CREW)
- **Installation on Following Vehicles**
  - M11XX HMMWVs
  - RG-31
  - Buffalo
  - Cougar

- **DC Power**
  - 28 VDC (14 VDC for engine controls)
  - 250/390 amp (Standard/High Idle)
  - Stationary Power (with vehicle in park) 15-20 kW
  - Alternator must fit in same location as OEM alternator
- **AC Power**
  - 3 phase 115V AC 400 Hz
  - 220V AC split phase 60 Hz
  - 120V AC single phase 60 Hz
  - Require no more than 30 HP to generate 15 kW
- **Power Management**
  - DC Objectives: 40 lbs / 1.5 cu. ft.
  - AC Objectives: 50 lbs / 1.5 cu. ft.

"The On-Board Mobile Power System is a vehicle mounted power generation system designed to support the high amperage requirements of current and future vehicle mounted Counter-Improvised Explosive Device (C-IED), Command & Control (C2) and Force Protection Systems."

Information extracted from need statement dated July 2006.

Note: Power requirements continue to evolve. Additional equipment will be added and/or removed from this system definition.

CERDEC Systems' Power Analysis Data

SYSTEM		Listed in Needs Statement	Voltage (DC)	CURRENT (Amps)		
				Standby	Nominal	Peak
Blowtorch		X	28	0.1	60	190
BFT	(Blue Force Tracker)	X	28	0.5	2.9	20
CREW	Current System	X	28	4.5	0	13
	Upgrade (Due Dec 06)		28	4.5	0	20
CROWS	M151 Protector	X	28	5	7	30
	XM101 CROWS		28	4	18	36
Gyrocam	GyroCam system		28	0	6	15
	Laserdyne Monitor		28	0	2	2
	Microwave		13.5	0	5	5
	Mast (w/ vehicle pneumatic)		28	0	0	2
	Mast (w/o vehicle pneumatic		28	0	0	22
Rhino		X	28	0	40	48
SCIMITAR			28	0	26	73
SINCGARS	VRC-87, 88 (Single Short Range)	X	28	1.0	2.1	4.0
	VRC-89, 91 (Short/Long Range)		28	1.3	8.7	14.0
	VRC-90 (Long Range)		28	1.0	2.0	4.0
	VRC-92 (Dual Long Range)		28	1.4	13.9	18.5
Spirit Hawk	Current Prototype		28	0.7	0.7	2
	Rugged Version (being designed)		28	2.9	2.9	8
TALON	(Battery Charger)		120 VAC	0	2.5	4

Note: Information displayed in this chart was provided by system PM Office, responsible RDEC, or system manufacturer's engineering department.

System owner recommended design load.

Denoted significant JIEDDO system requirements

CERDEC Power Generation Analysis

- **Analysis of** operational **current requirements shows that the vehicle will require 155 amps (HMMWV) and 173 amps (RG-31).**
- **Amperage (current) requirements significantly lower than stated in the Need Statement – decreased by more than 50%.**
- **Assumes all systems being used** at the same time **(worst case).**
- **On-board batteries will support short duration (< 1 sec) power spikes (common approach)**
- **TALON robot and Spirit Hawk not included in Need Statement.**
- **SCIMITAR not included per JIEDDO instructions.**
- **AC Power not required for interim solution**
- Inadequate power with existing equipment at curb idle.

System	M1114 (Amps @ 28 VDC)	RG-31 (Amps @ 28 VDC)
Basic Vehicle Load *	35	40
Battery Charging	5	5
SINCGARS **	13.9	13.9
Blue Force Tracker	2.9	2.9
Subtotal	56.8	61.8
CROWS	18	18
CREW	20	20
Rhino ***	N/A	N/A
Blowtorch	60	60
Gyrocam	N/A	13
Subtotal	98	111
TOTAL	154.8	172.8

* - RG-31 not verified at the time of this briefing

** - Load during dual channel long range transmission. During active receiving load drops to 1.4 A

*** - JIEDDO/REF indicate Rhino and Blowtorch not likely co-mounted. Blowtorch is worst case.

Potential HMMWV Solutions

Decision Summary

Potential Solution	Derated Amperage (A)	Excess Current (A)	Technical Risk	Operational Risk	Schedule	First Article Integration, Testing & Field Eval Costs	Fielding Cost (Per Unit)
400 A alternator, high idle setting	**275.2**	**120**	**Low**	**Med**	**120 days**	**$0.86 M**	**$ 8 K**
400 A alternator, enhanced pulley	**215**	**60**	**Low**	**Low**	**120 days**	**$0.86 M**	**$ 9.5 K**
400 A alternator, high idle setting, enhanced pulley	**309.6**	**155**	**Low**	**Med**	**120 days**	**$ 1 M**	**$ 9.5 K**
Fisher A5/60 Alternator	**250**	**95**	**Med**	**Low**	**120 days**	**$ 11.7 M**	**$ 36 K**
Fisher A5/60 Alternator, high idle	**392**	**237**	**Med**	**Med**	**120 days**	**$ 11.7 M**	**$ 36 K**

* Costs are engineering estimates as of 19 Oct.

Potential RG-31 Solutions

Decision Summary

Potential Solution	Derated Amperage (A)	Excess Current (A)	Technical Risk	Operational Risk	Schedule	Development First Article Integration, Testing & Field Eval Costs	Fielding Cost (Per Unit)
280 A alternator, high idle setting, enhanced pulley	**176**	**3.5**	**Low**	**Med**	**120 days**	**$ 0.550M**	**$ 9.7 K**
Fisher A5/60 Alternator (drop in)	**250**	**77**	**Med**	**Low**	**220**	**$1.08M**	**$16 K**
Fisher A5/60 Alternator, high idle	**392**	**219**	**Med**	**Med**	**120 days**	**$ 11.0 M**	**$ 46 K**
280 A Alternator & Fisher A5/60 Alternator Co-mount	**465**	**292**	**Med**	**Low**	**120 days**	**$ 11.0 M**	**$ 46 K**

* Costs are engineering estimates as of 19 Oct.

Strategies for Meeting CREW Spiral Power Increases

- Potential increases in near- and far-term power requirements due to new CREW spiral developments
- FY07 - <30-80A (Spiral 2.1)
- FY08 - <80-160A (Spiral 3.2)
- Estimates are “swags” – not based on actual technical information at present
- Likely to be much lower

HMMWV (M1114)

- **Current Recommended Technical Approach:**
  - 400A alternator with enhanced pulley
  - provides >60A extra power to current reqms
- **Spiral 2.1 (FY07) Technical Approach (if reqd):**
  - Use 400A alternator with enhanced pulley if final power increase <60A
  - Use 400A alternator with enhanced pulley with Automatic Throttle Control (ATC) if power increase >60A
  - Provides >75A excess power above CREW 2.1 reqm
- **Spiral 3.2 (FY08) Technical Approach (if reqd):**
  - Use 400A alternator with enhanced pulley with Automatic Throttle Control
  - Provides 155A of projected (conservative) spiral power requirement
  - Nearly meets even most pessimistic

RG-31

- **Current Technical Approach:**
  - 280A alternator with enhanced pulley and high idle
  - provides ~4A extra power to current reqms
- **Spiral 2.1 (FY07) Technical Approach (if reqd):**
  - Run parallel development of drop in 400A alternator (Fisher A5/60, Niehoff, or other).
  - Doesn’t meet 120day requirement due to lead time on alternator
  - Provides 77A excess power over current requirements
  - Substantially meets maximum potential requirement of 80A.
  - Cost only marginally higher (<$1M)
- **Spiral 3.2 (FY08) Technical Approach (if reqd):**
  - Use ~400A (Fisher A5/60, Niehoff, other) alternator with high idle setting
  - Add high idle to Spiral 2.1 solution
  - Provides ~219A extra power requirement over current requirements

SOLUTIONS
HMMWV – simply add ATC later (if reqd)
RG-31 – run parallel effort using different 400A (Fisher, Niehoff, or other)

Recommended HMMWV & RG-31 Solutions

VEHICLE	TECHNICAL APPROACH	SCHEDULE (Delivery to Theater)	FIRST ARTICLE INTEGRATION, TESTING & FIELD EVAL COSTS (15 HMMWV & 5 RG-31)	PRODUCTION / INSTALLATION COSTS Unit / Total (18669 HMMWV & 321 RG-31)	RISK & POTENTIAL ISSUES
HMMWV (M1114)	400A Niehoff Alternator w/ enhanced pulley	120 days	$ 0.860M	$ 9.5 K / $177.8 M	Low risk Availability of production alternator
RG 31	280A Niehoff w/ enhanced pulley and high idle	120 days	$ 0.550M	$ 9.7 K $3.1M	Moderate risk Availability of alternator Design of pulley and throttle control
	400A Alternator (Fisher A5/60, Niehoff, other) (Drop-in replacement)	220 days	$1.08M	$ 16 K $5.1M +	Moderate-High risk Availability of alternator Power Conditioning development

For RG-31, pursue 280A Niehoff solution initially.
Run parallel evaluation of larger (e.g. 400A) alternators in preparation for potential CREW spiral power requirements.

+ - Rough production cost estimate, will change with development

HMMWV On-Board Power Management Plan

15 - M1114 Vehicle Kits

- **Description:**
  - 400 Amp alternator upgrade with advanced pulley
  - AC/DC Inverter
- **Capability Gap**
  - Current 75 Amp at idle, min goal 155 Amp with a target of 200Amp at idle.
- **Program**
  - OBP JUONS
  - Quantity: Total 15 # OIF 0 # OEF
  - POC PM: Robert Rappold, PM LTV, DSN 786-2319
  - POC TARDEC: Andrew Schultz, Engineering, DSN 786-5075

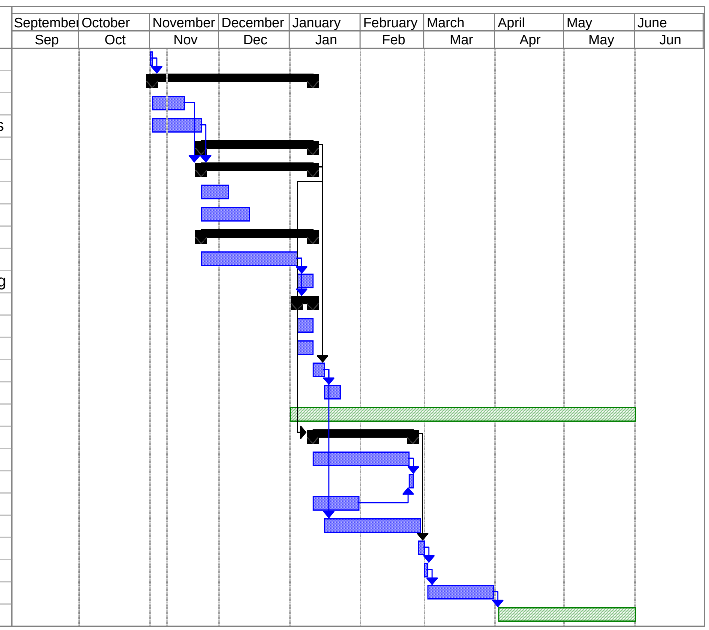
• Funding

Event	Funding Request	Obligated	Remaining
Management	**$175,000.00**		
Engineering/Test	**$350,000.00**		
Integration	**$20,000.00**		
Documentation	**$35,000.00**		
Component Acquisition	**$207,000.00**		
Transport	**$3,000.00**		
Field Support	**$70,000.00**		
TOTAL	**$860,000.00 (includes 15 kits)**		
Production*	**$177.8 M for 18669 vehicle kits**		

Projected 1st KIT in Theater : 1 March 07 based on start date of 01 Nov. * Engineering estimate

• Schedule:

ID	Task Name
1	Start of Work Meeting
2	**Prototype**
3	Secure Vehicle
4	Order prototype componets
5	**Engineering**
6	**OBP INTEGRATION**
7	Alternator
8	Inverter
9	**Pulley**
10	Delivery
11	Functional testing
12	**Durability testing**
13	Bracket
14	Wiring Changes
15	Assembly
16	System Functional testing
17	Vehicle Testing @ APG
18	**KIT Production**
19	Delivery of Components
20	KIT assembly
21	Fabrication
22	Documentation
23	Ship Parts to Theater
24	Parts Arrive in Theater
25	KIT installation
26	User Evaluation



As of: 13 Nov 06

RG-31 OBVP (280A) Management Plan

- **Description:**
  - 280 Amp alternator upgrade with advanced pulley
  - AC/DC Converter
- **Capability Gap**
  - Current 100Amp alternator, 65 Amp at idle .
  - min goal 173 Amp with a target of 200 Amp at idle.
- **Program**
  - OBP JUONS
  - Quantity: Total 5 # OIF 0 # OEF
  - POC PM: Ross Boelke, PM AMS, DSN 786-8852
  - POC TARDEC: Sean Tominna, Engineering, DSN 786-8909

• Funding

Event	Budget	Obligated to date	Remaining
Management	$175,000.00		
Engineering/Test	$200,000.00		
Integration	$20,000.00		
Documentation	$14,800.00		
Component Acquisition	$107,000.00		
Transport	$3,000.00		
Field Support	$30,080.00		
TOTAL	$549,880.00 (includes 5 kits)		
Production*	$3.1M (includes 321 kits)		

Projected 1st KIT in Theater : 1 March 07 based on start date of 01 Nov. * Engineering estimate

• Schedule:

ID	Task Name
7	Alternator
8	Inverter
9	**Pulley - Niehoff**
10	Delivery
11	Functional testing
12	Durability testing
13	Bracket
14	Wiring Changes
15	**DC/AC Inverter Integ**
16	Assembly
17	System Functional tes
18	**KIT Production**
19	Delivery of Componer
20	KIT assembly
21	Fabrication
22	Documentation
23	Ship Parts to Theater
24	Parts Arrive in Theater
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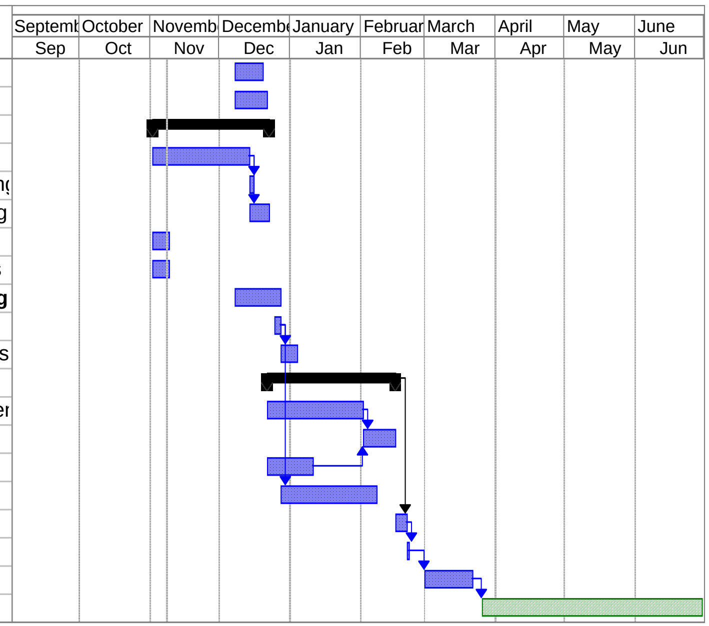
26	User Evaluation



As of: Date

Path Forward

- JRAC supported recommendations
- Funding received January 2007
- TARDEC executing program
  - Components identified
  - Technical integration issues resolved
  - Testing on-going at Yuma Proving Grounds
  - Fielding to theater for evaluation in May
- 2nd Phase RG-31 solution pending
- Funding for implementation deferred until field tests completed
- Lessons learned to be transitioned to USMC and JLTV programs

DISCUSSION

Flexible Hybrid Power Architecture and Evaluation of Multiple Sources Under Load

25 Apr 07

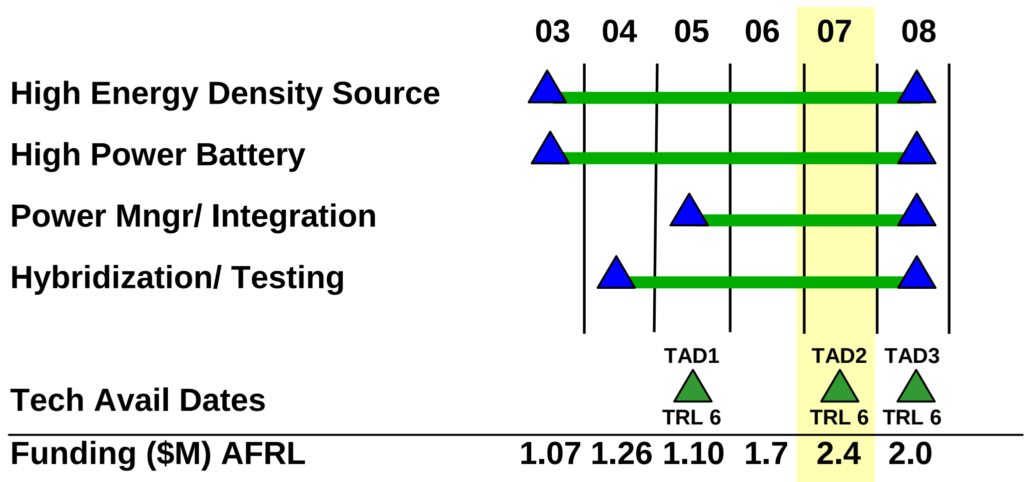
Lt Josh Johnson
Propulsion Directorate
Air Force Research Laboratory
joshua.johnson@wpafb.af.mil

BRITES

AFRL/PR

Technology Investment Schedule (FY) As of: 14 Aug 06

Spiral Development/Transition



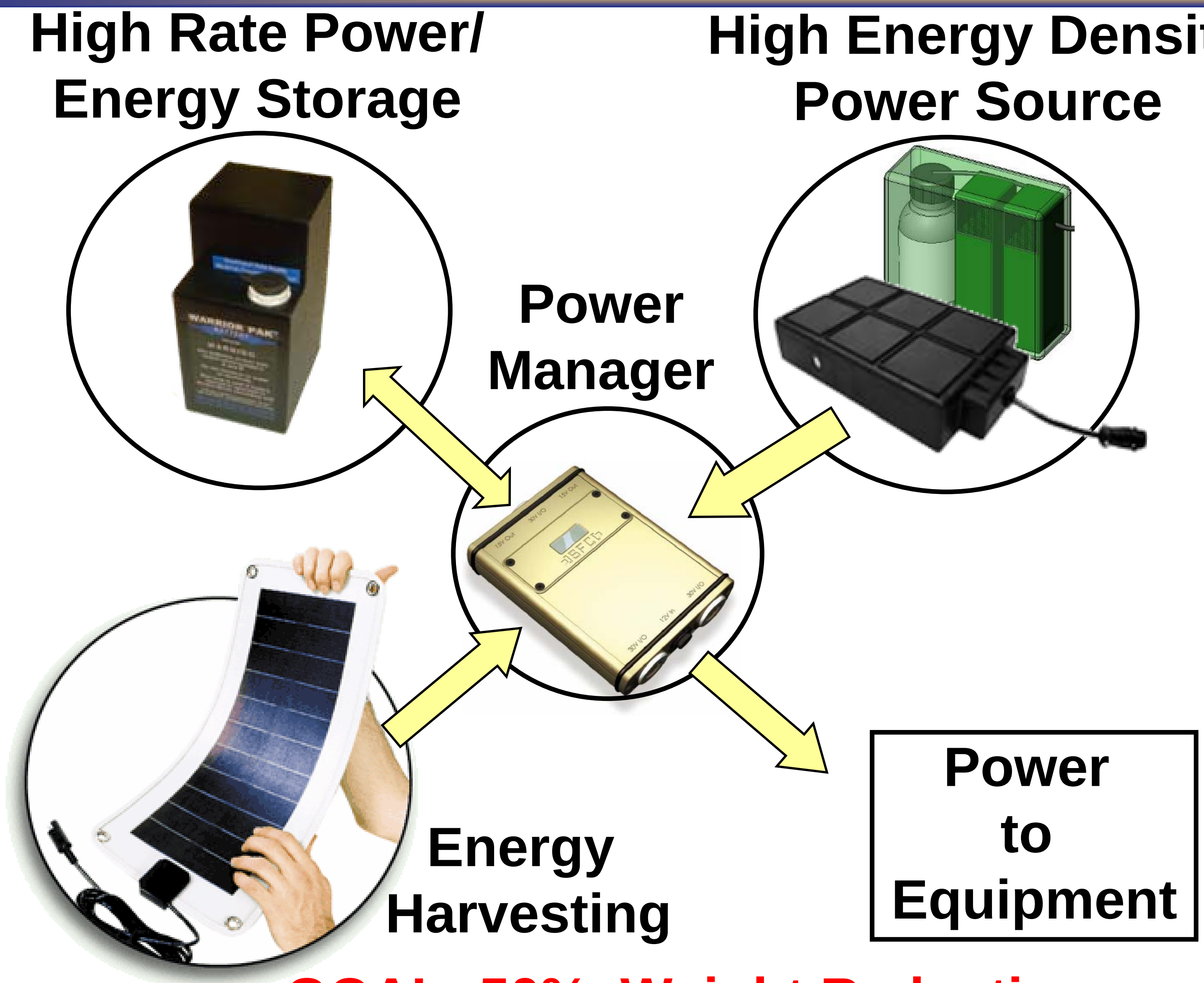
Description	Benefits to the War Fighter
Hybrid renewable energy sources deliver same energy in less weight.	• 50% reduction in weight over current batteries • Energy harvesting allows war fighter to recharge from multiple sources in the field • Easily upgradeable in the future • Versatility will accommodate/interface with new equipment
Technology	
• Optimized Li Ion battery for high power requirements • High Energy Density Fuel Cells • Intelligent Power Management harvests energy	

Airman Energy Need

- **Battlefield Airmen operate a wide range of electronic equipment in order to image, target, compute, and communicate**
- **Airmen are often limited to the resources they can carry on their backs**

Power
Average: 25-50W
Peak: 400W
Mission Length: 1-14 days

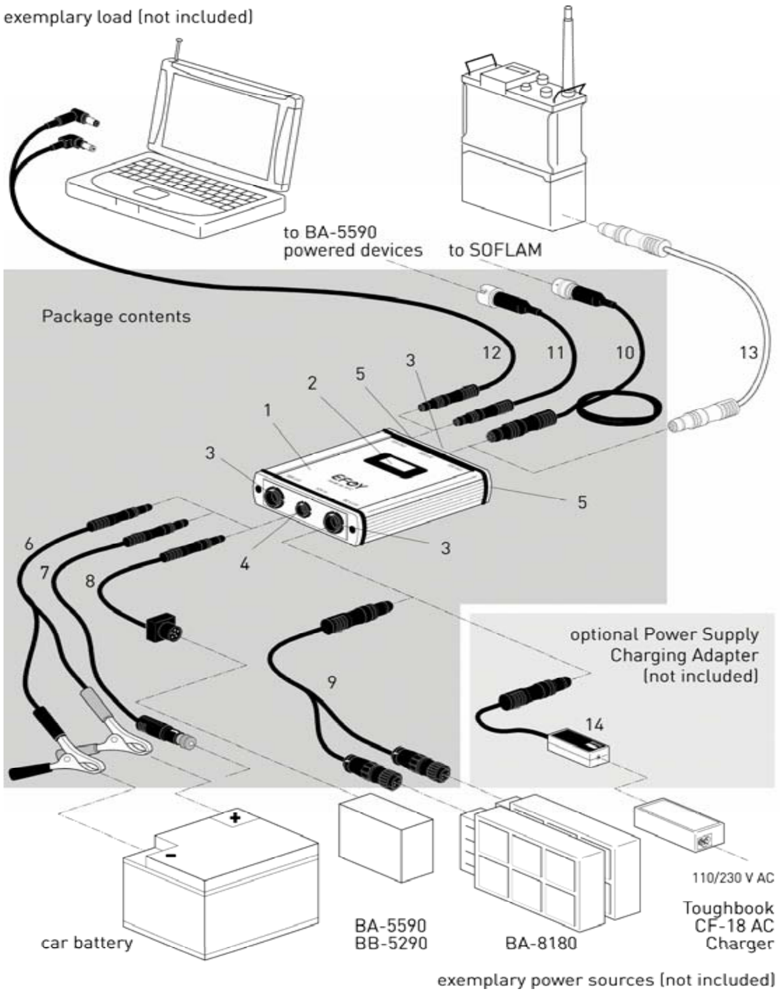
BRITES Solution



GOAL: 50% Weight Reduction

BRITES Spiral 1

- Spiral 1 System
  - MediPak Li Ion battery
  - SFC Power Manager
  - Electric Fuel Zn Air battery
- Passed Developmental Tests
  - Jul 06
- Passed Operational Tests
  - Sept 06
- Currently in LRIP



BRITES Spiral 2

- Two contracts for Fuel Cells and Power Manager
  - Smart Fuel Cell
  - Protonex

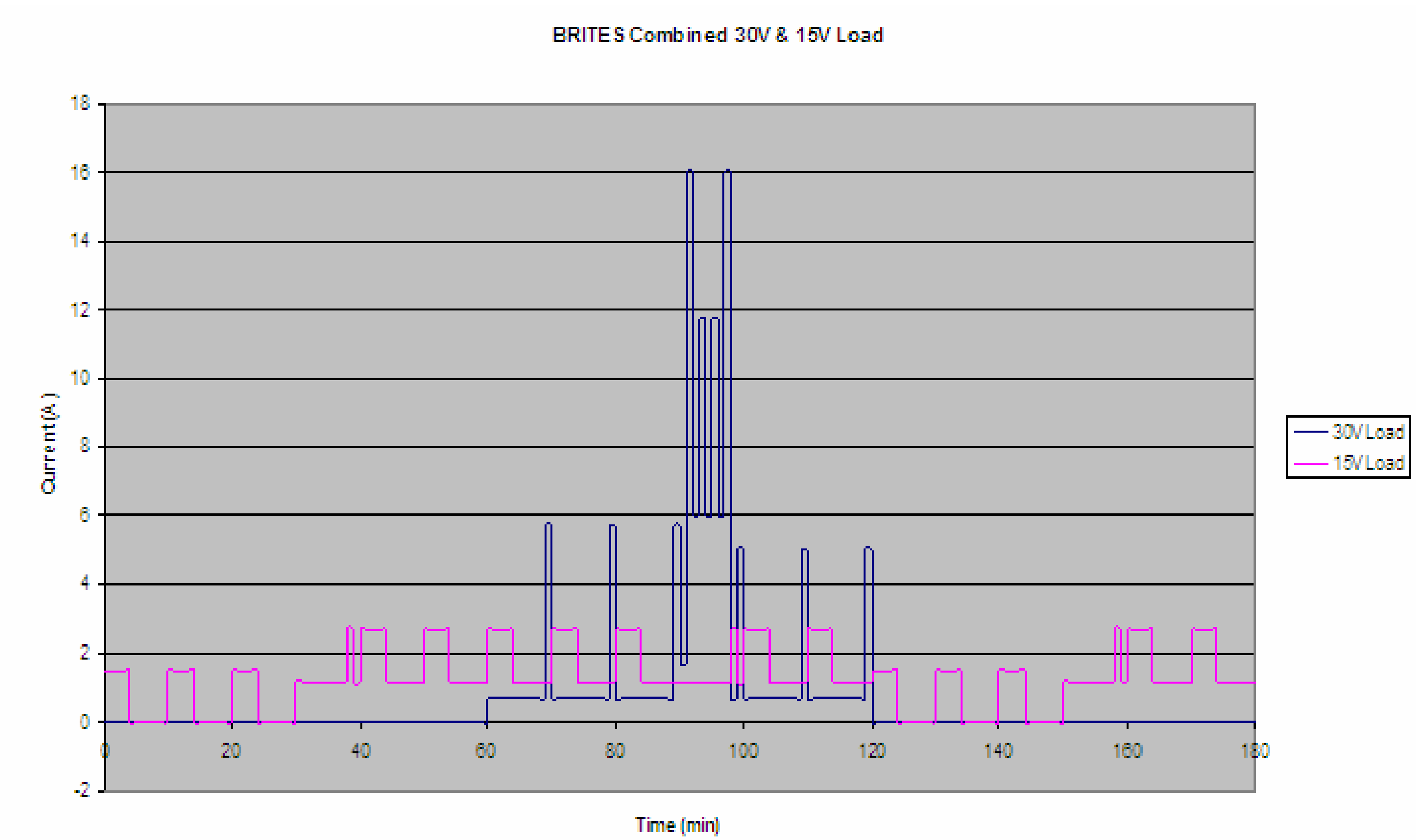
- Two contracts for optimized Li Ion battery pack
  - Microsun
  - MediPak

- Received all systems 2Q FY07
- Currently testing various combinations of power sources

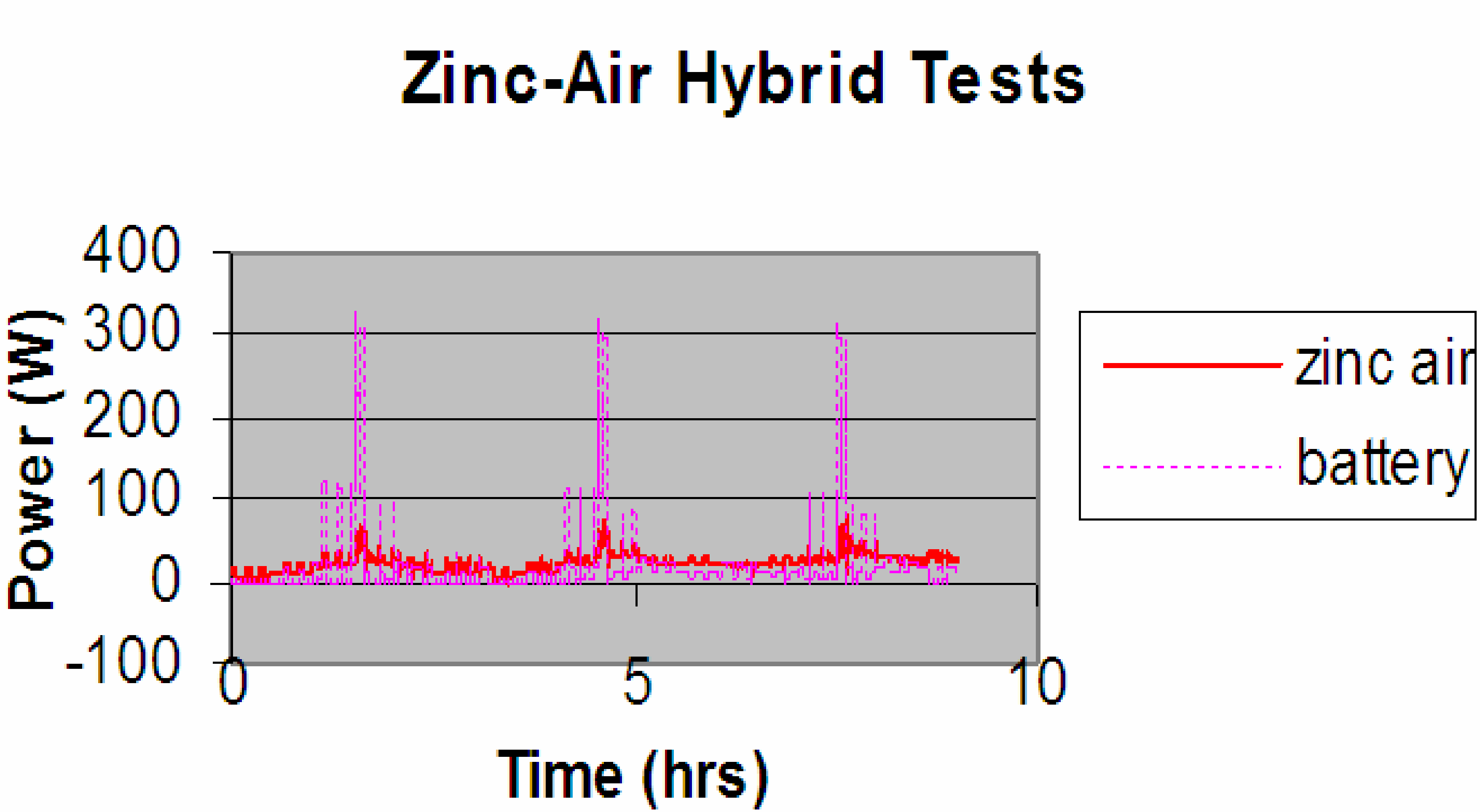
BRITES Testing

- Goal: Take several state-of-the-art fuel cells, batteries, and solar panels and test them under realistic load conditions in a hybridized system
- Test Setup:
  - MicroSun battery was used as Li Ion battery pack
  - Protonex power manager used to connect to all sources and all loads
  - Various power sources include: Ultracell, Protonex, AMI, SFC, Zn Air, and solar
  - Load profile developed for both 30V and 15V output, 40W average over 3hr cycles

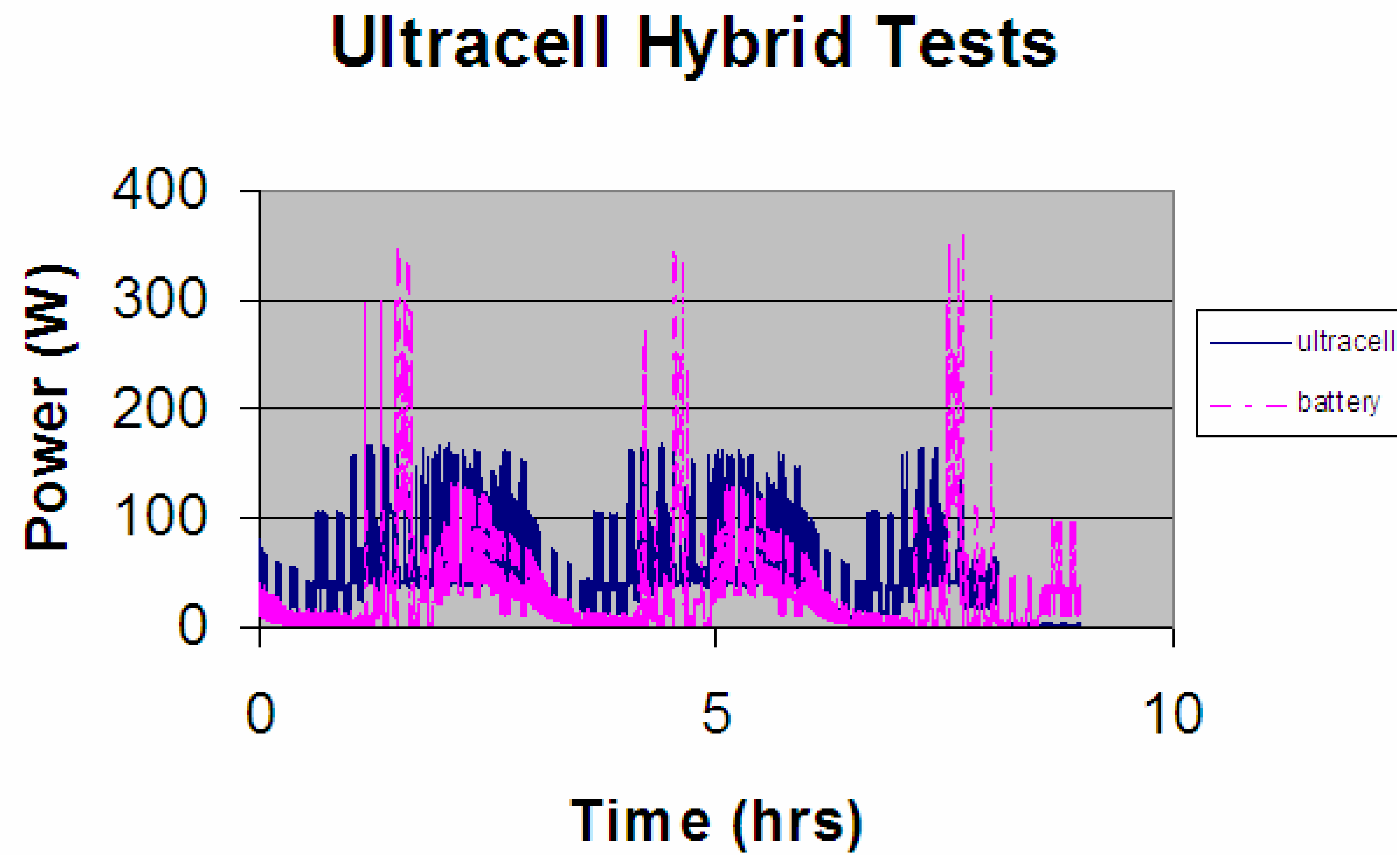
BRITES 30V & 15V Load Profile



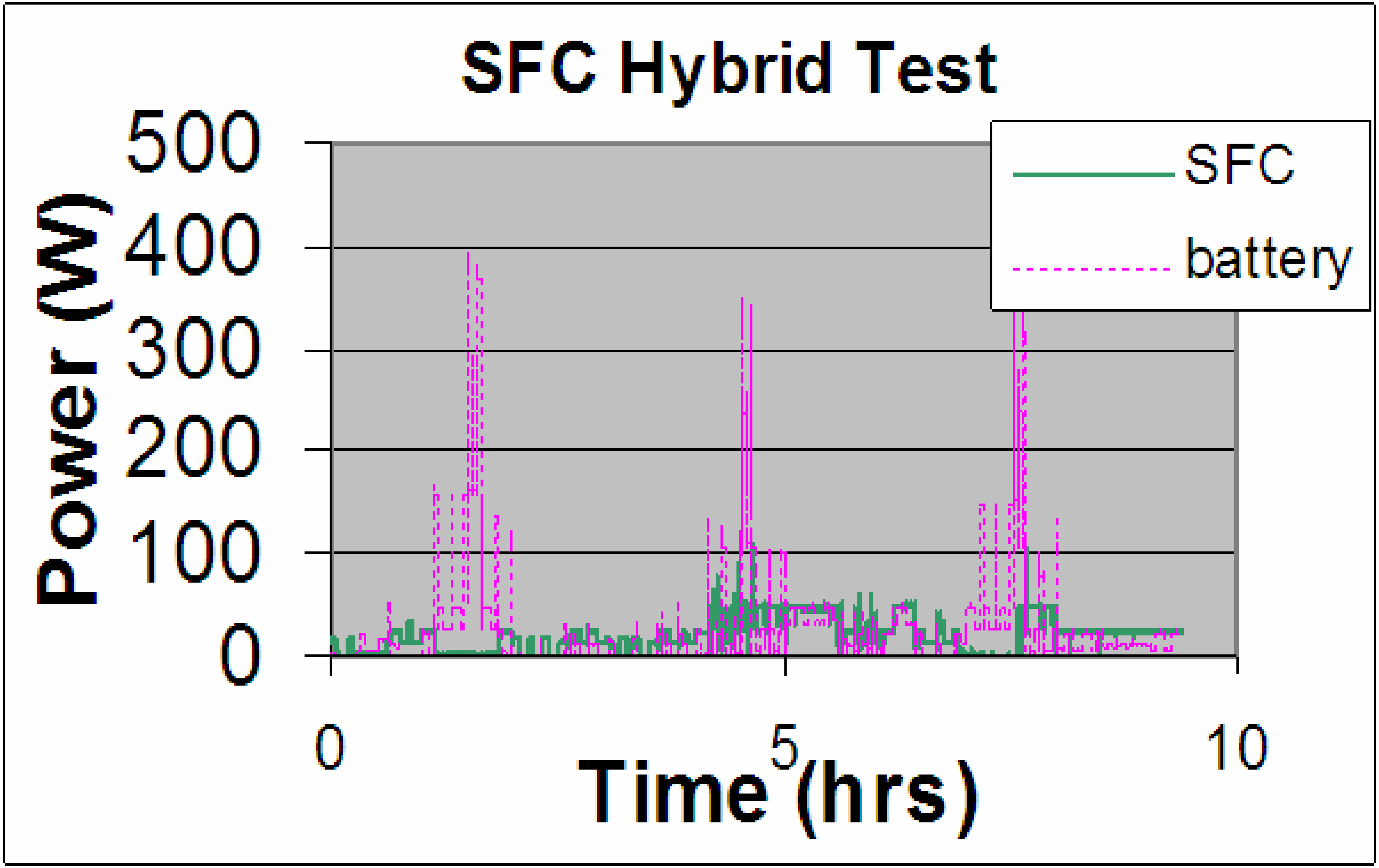
Zn Air Hybrid Testing



Ultracell Hybrid Testing



SFC Hybrid Testing



Solar Hybrid Testing

- Solar panel provided ~5W under hybrid load
- Solar panel provided as much as 42W charging battery only
- Some work must be done on Peak Power Tracking algorithm
- System capable of harvesting energy from:
  - 5590s
  - Cigarette adapters
  - Power supplies
  - Car batteries directly

Current Evaluation

- System has shown “power source agnostic” capability
  - System can draw power from multiple fuel cells of different types
  - System can draw power from alternative sources, i.e. solar
- Increased energy density is achievable over 5590s
  - 25% weight savings for Spiral 1 (MediPak battery, Zn Air battery, SFC power manager)
  - Initial test indicates 33% weight savings for Spiral 2 (Microsun battery, SFC fuel cells, SFC power manager)
- Power Manager provides increased situational awareness of power usage
- Power Manager key to providing control over fuel cell operation and hybridization
- But several challenges still ahead…

Hybrid Challenges

- Fuel Cell reliability
  - Could not run tests on all available fuel cells
  - Several fuel cells failed during testing
  - Goal: To run hybrid test for 72hrs straight
- Fuel Cell stability
  - Control needed when combining 2 or more fuel cells sharing load
- Power Manager Communication
  - Power Manager could not communicate with all fuel cells or batteries
  - Better communication and control of fuel cells needed

Hybrid Challenges

- Power Manager Information
  - Power Manager provided some but not all system information – Battery SOC, Fuel Level, Output Voltage, etc.
- Power Manager Peak Power Tracking could Improve
  - Implement better algorithm
- Ruggedization and Reliability need to be increased in fuel cell technology
- Integration on rucksack and cable management can be improved

BRITES Spiral 3

- Continuing to develop high energy density sources in conjunction with other DoD agencies
- Power management development will finish out under existing contracts
- FY08 last year for AFRL funding
- Integration a lead challenge to make multi-technology energy system fieldable with future equipment suite
- AFRL plans to contract a leading integrator for Spiral 3 systems
  - Opportunities exist to insert high energy density (>600Wh/kg) technologies under this effort

AutoDISE

MSgt Fred McCue
Project Officer - Mobile Electric Power
Fred.mccue@usmc.mil

Agenda

- History
- System Capabilities
- USMC Version

AutoDISE History

AutoDISE is the current U.S. Army computer based electrical camp planning tool.

Information and downloads are available on the internet at http://www.autodise.net/

- Computer model developed to simulate the use of:
  - Distribution Illumination System, Electrical (DISE),
  - Power Distribution Illumination Systems, Electrical (PDISE).
- Designed for the use in Army systems
- Uses graphics interface.
- Standalone client application
- No formal install
- Run directly off of a CD

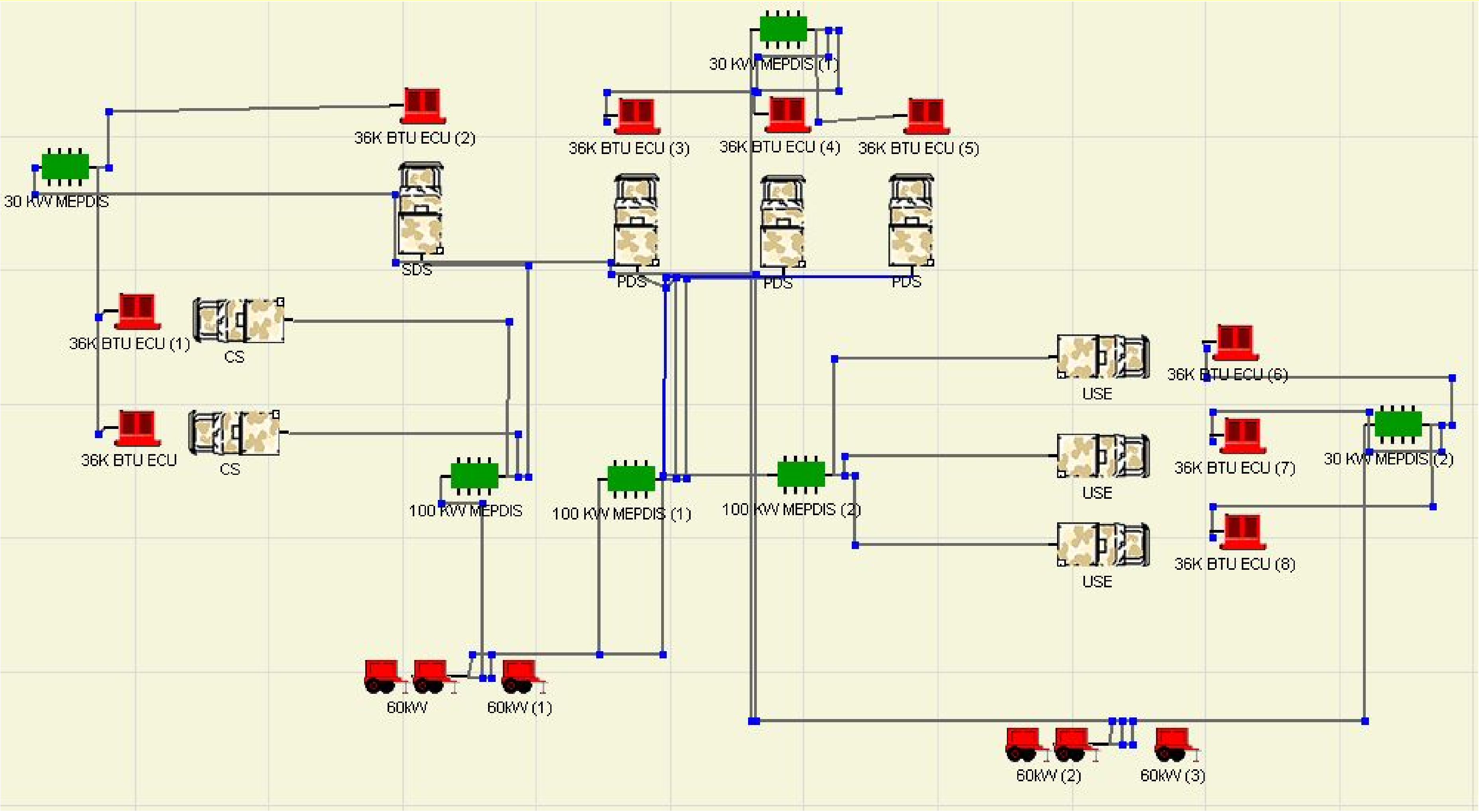
AutoDISE History

- **AutoDISE is used to engineer Army DISE Layouts for systems that consist of:**
  - **Multiple shelters,**
  - **Electrical consumers, and**
  - **Electrical power generators.**
- **DISE (Army) and MEPDIS (USMC) consists of electrical cables, connectors, feeder centers, and distribution centers that are used to distribute electrical power to the equipment.**
- **A user of AutoDISE should refer to the operator and maintenance manual for MEPDIS**
  - ***It is the authority over information presented in the user's guide and software.***

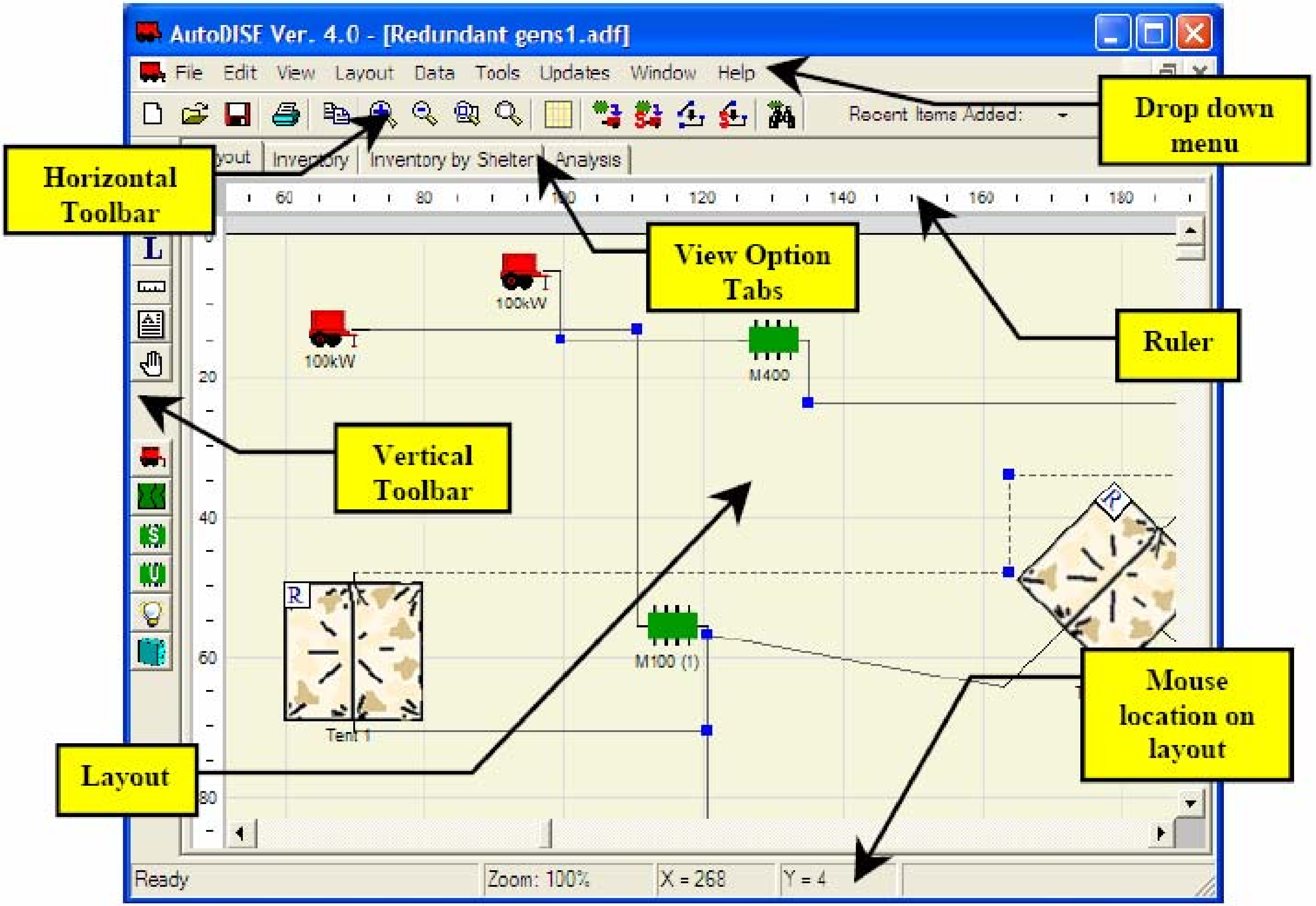
System Capabilities

- Camp layouts to scale.
- Required equipment inventory.
- Phase balancing.
- Automatic connection of power distribution and power consuming items.
- Individual tent/shelter layouts.
- System analysis to include total kw, total loads, and available kW.
- User defined power distribution systems.
- User defined loads.

System Capabilities

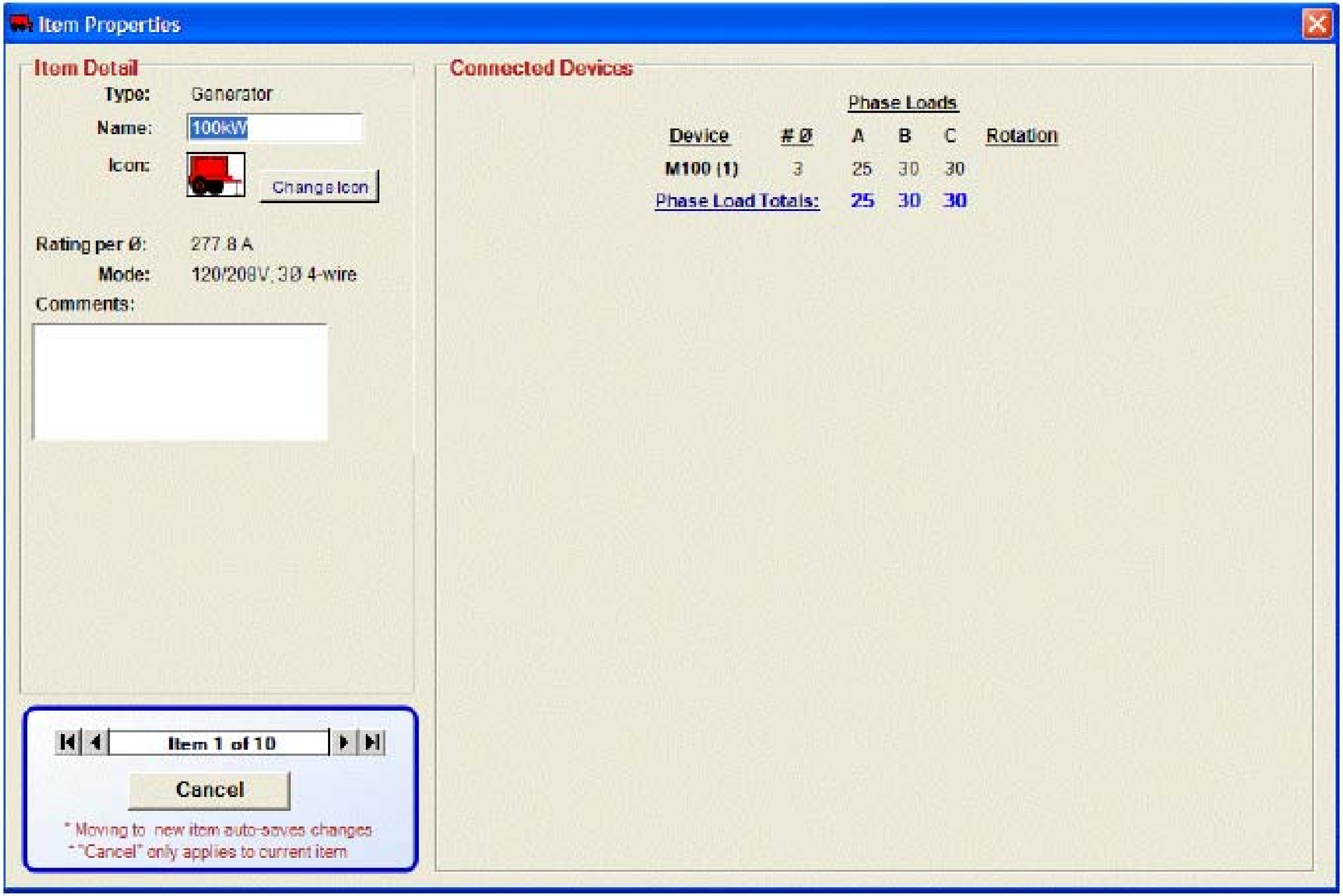


System Capabilities



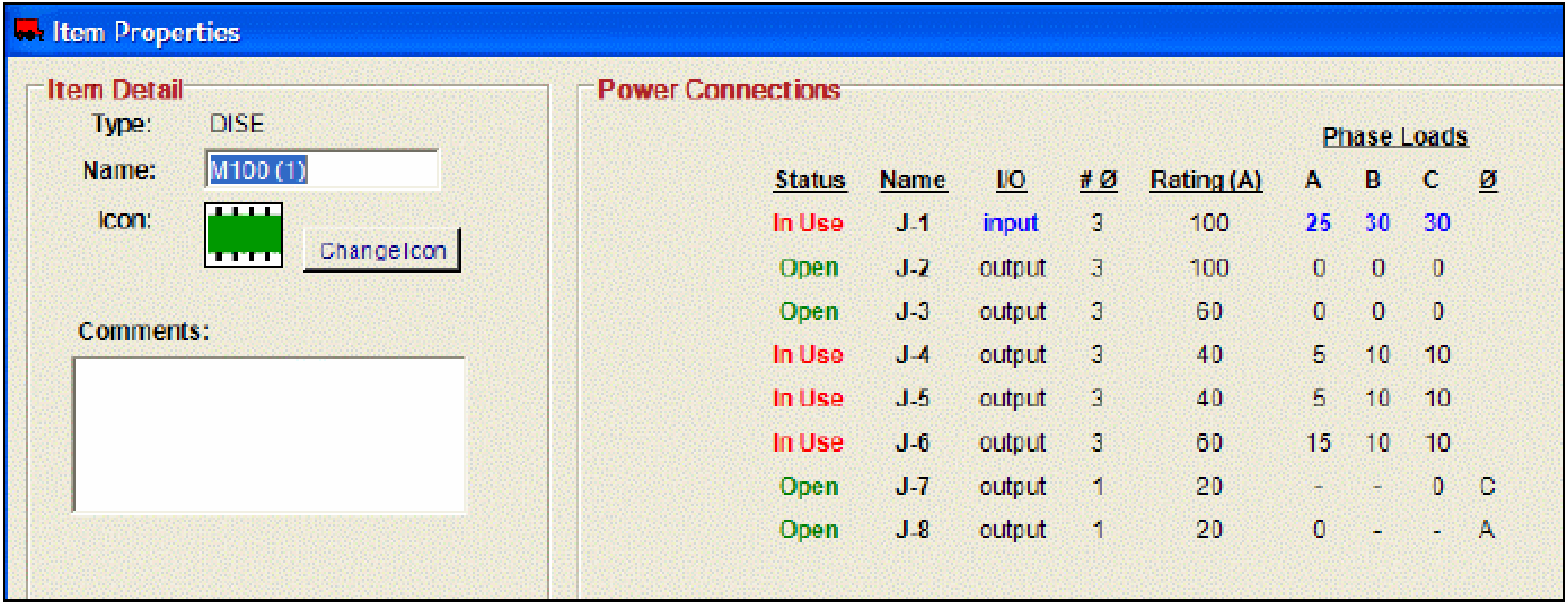
Windows based pull down menus with drag and drop capability.

System Capabilities



Ability to view each generator set and connected devices with load and phase details.

System Capabilities



Status	Name	I/O	# Ø	Rating (A)	A	B	C	Ø
In Use	J-1	input	3	100	25	30	30	
Open	J-2	output	3	100	0	0	0	
Open	J-3	output	3	60	0	0	0	
In Use	J-4	output	3	40	5	10	10	
In Use	J-5	output	3	40	5	10	10	
In Use	J-6	output	3	60	15	10	10	
Open	J-7	output	1	20	-	-	0	C
Open	J-8	output	1	20	0	-	-	A

User can view each individual power distribution panel and all connected loads. The system allows views of available connection points. Also an automatic phase balancing feature will notify the user when phases are outside of user defined tolerances.

System Capabilities

Layout | Inventory | Inventory by Shelter | Analysis

Layout Inventory (Click on column headers to sort) **Print** **Export**

Type	Name	Mode	Quantity	In Shelter?	# Ø	AC/DC	Generator
Generator	10kW	120/208V, 3Ø 4-wire	1	No	3	AC	10kW
Breaker Panel	A BOX	-	1	Yes - ICU (1)	3	AC	Not connected
Breaker Panel	A BOX	-	1	Yes - PLX	3	AC	Not connected
Breaker Panel	A BOX	-	1	Yes - ICW	3	AC	Not connected
Breaker Panel	A BOX	-	1	Yes - ICU	3	AC	Not connected
Breaker Panel	A BOX	-	1	Yes - Radiology Tent	3	AC	Not connected
Breaker Panel	A BOX	-	1	Yes - PRE-OP/CMS/POST-OP	3	AC	Not connected
Breaker Panel	A BOX	-	1	Yes - TOC	3	AC	Not connected
Breaker Panel	A BOX	-	1	Yes - ICU (2)	3	AC	Not connected
Breaker Panel	A BOX	-	1	Yes - Sanitation Center	3	AC	Not connected
Breaker Panel	A BOX	-	1	Yes - TOC	3	AC	Not connected
Breaker Panel	A BOX	-	1	Yes - Feeding Tent	3	AC	Not connected
Breaker Panel	A BOX	-	1	Yes - Company HQ	3	AC	Not connected

Ability to export inventories to Excel, MS Word, or Adobe PDF Files.

USMC Version

- **USMC final version will include Army systems, plus:**
  - **Old USMC MEPDIS,**
  - **New USMC MEPDIS,**
  - **USMC Field Wiring Harness,**
  - **All standard cable sets**
- **Ability to recognize paralleled generator sets**
  - **Beyond the Army power plant model,**
  - **Including operating in parallel through the new MEPDIS.**
- **Warning when generator is running under wet stacking conditions**

USMC Version

- **CD-ROM will be the delivery medium**
  - **To be run as stand alone application**
  - **Will not be NMCI supported**
  - **Data files will need to be stored to your computer**
- **Crib-sheet handout for quick reference**
- **PowerPoint training package**
- **Final version available now.**

Fielding Issues

- CDs are available now.
- See your FSR for your copy and training.

IF NOTHING ELSE, REMEMBER THIS:

- **AutoDISE does not take the place of formal school training.**
- **It is designed to be used by someone trained in electrical camp planning.**

Questions ?

PROGRAM MANAGER
EXPEDITIONARY POWER SYSTEMS
MARINE CORPS SYSTEMS COMMAND

Tactical Generators

MSgt Fred McCue
Project Officer Mobile Electric Power
fred.mccue@usmc.mil

Agenda

- Current Family of Equipment
- Recent Additions
- Supporting Efforts
- Equipment Buys and Deliveries

Family of Mobile Electric Power

2KW 60HZ MEP-531A TAMCN B0980

3KW 60HZ MEP-16B TAMCN B0730

3KW 60HZ MEP-831A TAMCN B0730

10KW 60HZ MEP-003A TAMCN B0891

10KW 60HZ MEP-803A TAMCN B0891

10KW 400HZ MEP-813A TAMCN B0921

20KW 60HZ MMG-25 TAMCN B0930

30KW 60HZ MEP-005A TAMCN B0953

30KW 400HZ MEP-114A TAMCN B0971

30KW 60HZ MEP-805A/B TAMCN B0953

30KW 400HZ MEP-815A/B TAMCN B0971

60KW 60HZ MEP-006A TAMCN B1021

60KW 400HZ MEP-115A TAMCN B1016

60KW 60HZ MEP-806A/B TAMCN B1021

60KW 400HZ MEP-816A/B TAMCN B1016

100KW 60HZ MEP-007A/B TAMCN B1045

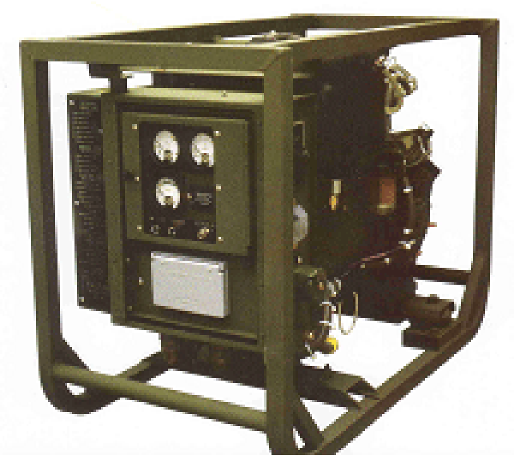
100KW 60HZ MEP-807A TAMCN B1045

ITEMS IN RED ARE AT, OR BEYOND, THE END OF THEIR LIFE CYCLE AND ARE BEING REPLACED

Recent Addition – B0980

Technical / Performance Data

- **Model:** MEP-531A Military Tactical
- **Weight:** 152 lbs (wet)
- **Fuel:** Diesel & JP-8
- **Noise:** 79dBA @7m
- **Starting:** Manual and Slave Start
- **Fuel Usage:** 0.33 gph
- **Dimensions:** 30" L x 16" W x 22" H
- **Output:** 2 kW @ 120 VAC, Single Phase, 60Hz
- **Transport:** Man-Portable
- **Acquisition:** Currently being fielded



General usage for this item is for remote security lighting and to replace commercial man-portable sub 2kw units already in use.

Currently 455 sets have been received.

36 for MARFORRES, 83 in support of the UOC program and 197 for Operating Force units.

Recent Addition – B0930

Technical / Performance Data

- **Model:** MMG25 (USMC Configuration)
- **Weight:** 2200 lbs. (wet)
- **Fuel:** Diesel & JP-8
- **Noise:** 65 dBA @23 ft.
- **Starting:** Electric
- **Fuel Usage:** 2.1 gph
- **Dimensions:** 77" L x 35" W x 52" H
- **Output:** 22 kW 120/208, Three Phase
- **Transport:** HMMWV towable (M-116 / LTT-MCC)
- **Acquisition:** Continued purchase by MARCORSYSCOM
- **Support:** Direct Vendor support for supply

This unit was originally purchased based off an Urgent Needs Statement from OIF. The equipment was brought into the inventory specifically to support the TRC-170.

Currently 74 sets are in Iraq, 6 in MARFORRES, 20 at III MEF, 28 at II MEF and 26 at I MEF.

A full O & I level military TM with cataloged (NSN assigned) parts is under development and is scheduled for completion by the end of April 07.

Recent Addition – B1045

Technical / Performance Data

- **Model:** MEP-807A
- **Weight:** 5860 lbs.
- **Fuel:** Diesel & JP-8
- **Noise:** 72dBA @7m
- **Starting:** Electric
- **Fuel Usage:** 7.85 gph
- **Dimensions:** 106" L x 40" W x 65“ H
- **Output:** 100 kW @ 120/208/240/416 VAC
- **Transport:** MTVR new trailer, LVS
- **Acquisition:** **F**ielding began in 2006

USMC received its first sets in April 06 and were used to meet a critical MPF Shortfall.

22 sets were fielded to II MEF in November 2006. The first 7 of 50 sets for I MEF are here now.

All MEFs will receive some sets and New Equipment Training before the end of FY07.

380 sets have been purchased 190 sets will be delivered to the USMC before the end of CY07.

72 of the sets were purchased by PM-Engineers to support the new Containerized Batch Laundry System

Supporting Efforts

- Field Service Representatives (FSR) within each MEF and forward deployed to Iraq.
- MARCORSYSCOM funded Training FSR based at Marine Corps Engineer School (MCES).
- Inclusion of MCES and Operating Forces personnel in equipment demonstrations and evaluations.
- Enhanced New Equipment Training (NET) with follow on training available.

Equipment Buys – PEI Rotation

- $91M in equipment buys in FY05, FY06 and FY07.
- 618 - 3kW, 60hz sets
- 1453 - 10kW, 60hz sets
- 39 - 10kW, 400hz sets
- 134 - 22kW, 60hz sets
- 1139 - 30kW, 60hz sets
- 13 – 30kW, 400hz sets
- 444 - 60kW, 60hz sets
- 22 - 60kW, 400hz sets
- 380 - 100kW, 60hz sets

Major Deliveries

ITEM	QTY	DESTINATION	DELIVERY DATE
MEP-831	522	ALBANY	MARCH 2006 -APRIL 2007
MEP-803A	219	ALBANY	FEBRUARY-MARCH 2007
MEP-803A	130	ALBANY / BARSTOW	APRIL-AUGUST 2007
MEP-805B	240	ALBANY	JULY-AUGUST 2006
MEP-805B	90	BARSTOW	JUNE 2007
MEP-805B	140	ALBANY	OCTOBER 2007
MEP-806B	50	ALBANY	APRIL 2007
MEP-807A	34	ALBANY	APRIL 2007
MEP807A	32	ALBANY	MAY 2007
MEP807A	31	ALBANY	JUNE 2007

This table shows major equipment deliveries only. Smaller shipments will arrive. Information on equipment availability is available from the Project Officer or Equipment Specialist. Because of the need to Reset the Force and Principle End Item (PEI) rotation requirements, most equipment purchase are being directed to Albany. All using units, regardless of location, will still have backorders filled as equipment becomes available.

Fielding Issues

- New generators replace old hardware; get rid of the old.
- Ensure you factor new equipment into your embark & pre-deployment plans.
- Ensure your Marines get trained.
- Submit TOECRs via TFSMS to change allowances.

IF NOTHING ELSE, REMEMBER THIS:

- **New equipment is continuously arriving.**
- **Ensure your backorders are submitted properly.**
- **Contact the Material Manager or Equipment Specialist at Albany if you are not receiving the replacements you need.**
- **Contact your FSR for technical assistance or remedial training.**

Questions ?

BAE SYSTEMS

Power-Managed HMMWV Demonstrator

Joint Service Power Expo
April 25, 2007

BAE SYSTEMS

Problem statement

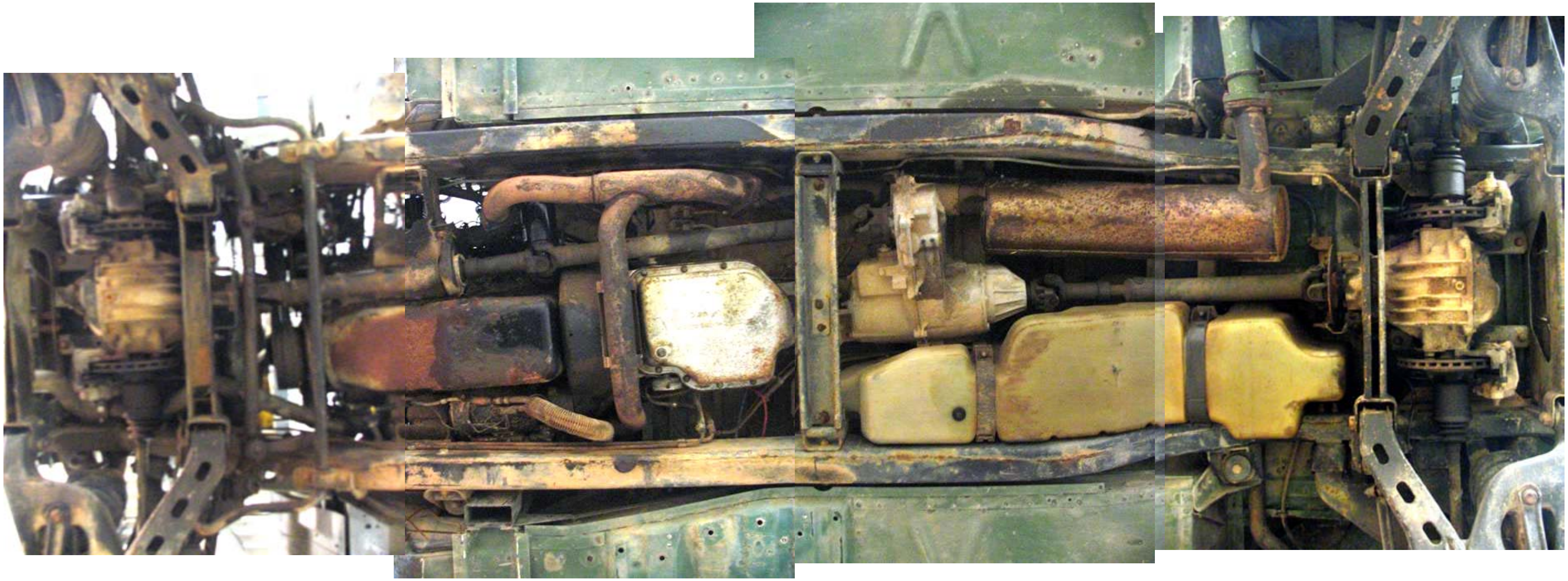
- There is an urgent theater requirement for a self protection and IED defeat suite of subsystems on tactical wheeled vehicles (TWVs)
- HMMWV and EOD armored trucks (i.e. Buffalo, Cougar, RG31, etc.) do not have enough electrical power for this equipment
- The immediate power requirement is for 28VDC… 400 amps across the entire engine operating range
  - ONR/USMC OBVP program is developing AC export power
  - 115/230VAC is a *future* requirement for IED defeat
- DoD is seeking alternatives

Urgent Warfighter need

HMMWV integration considerations

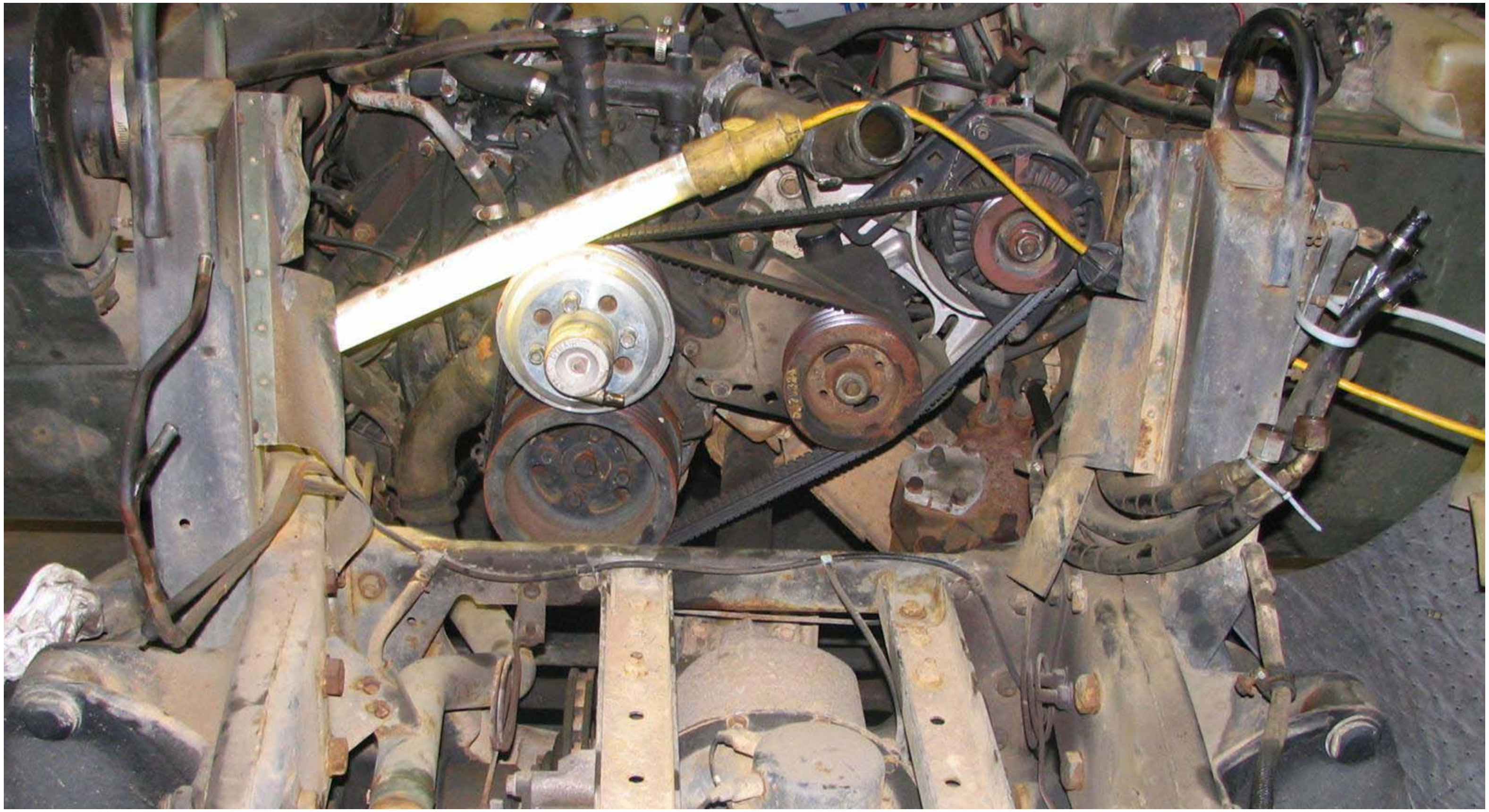
BAE SYSTEMS

HMMWV chassis packaging

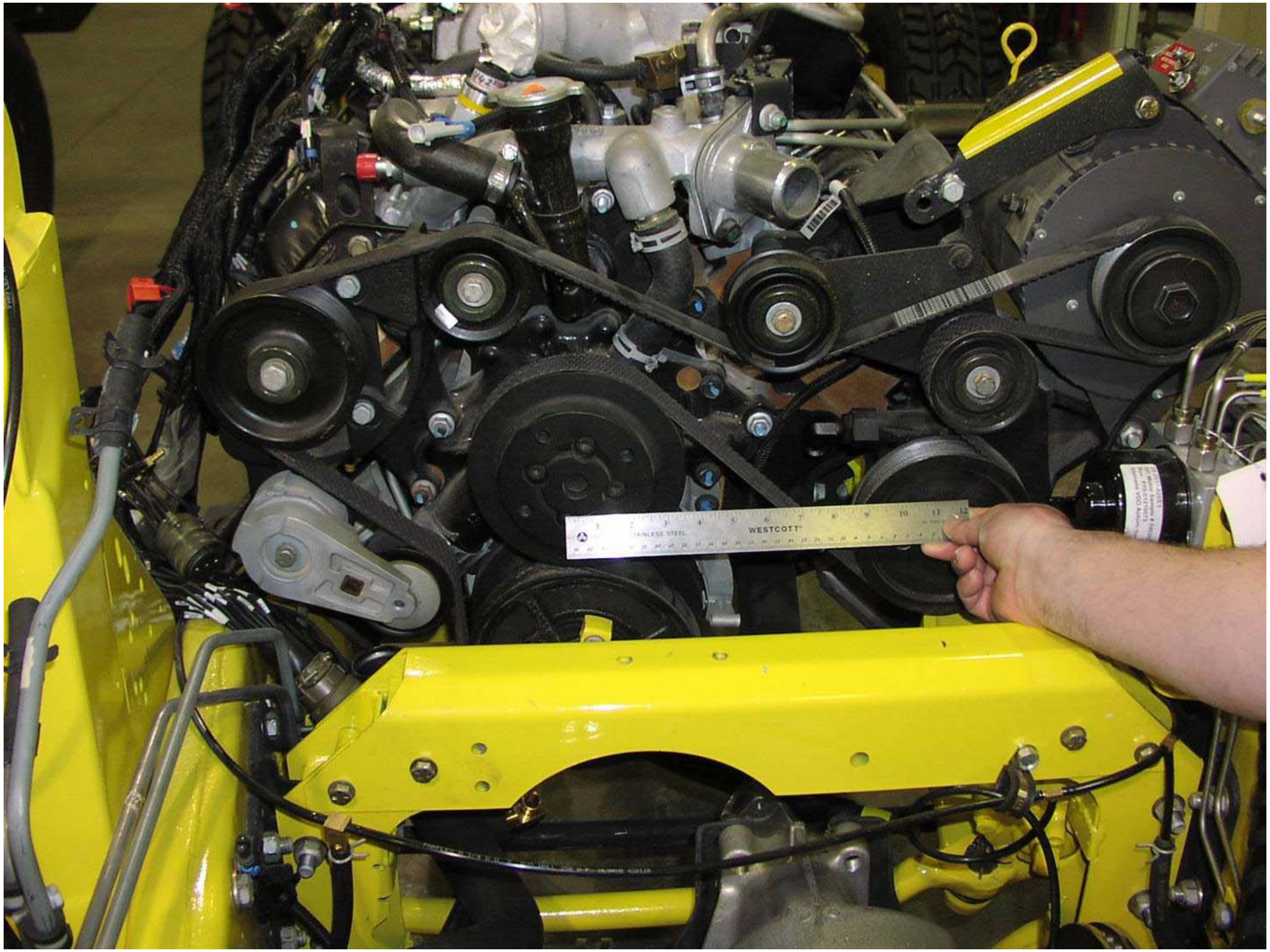


No space claim available under the chassis

HMMWV engine with v-belts (old 6.2L)



HMMWV engine with serpentine belt (new 6.5L)

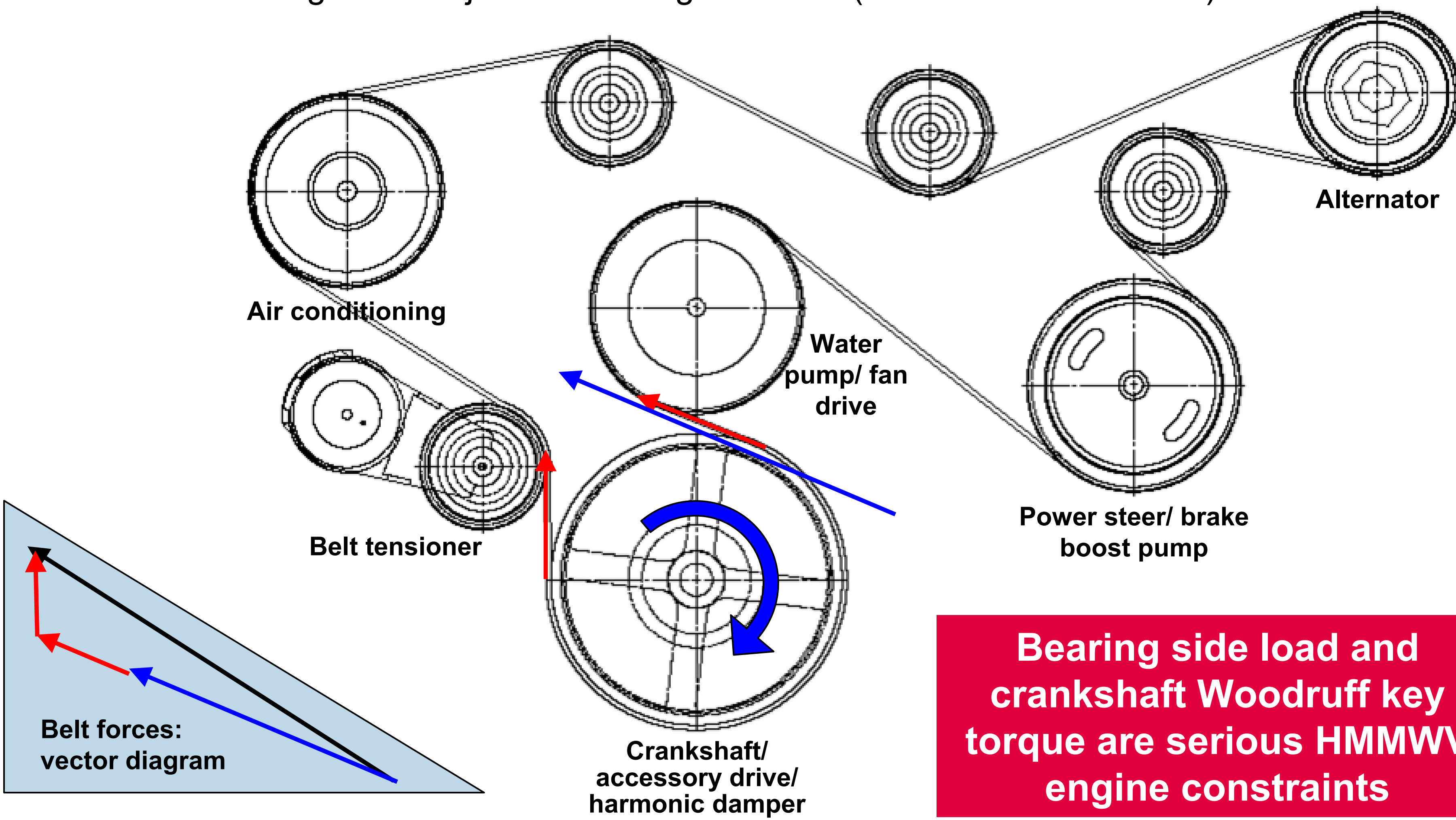


A) Static belt tension force vector

B) Pulley torque force vector (acts on crankshaft key)

C) Pulley torque reaction force (due to sum of all mechanical loads)

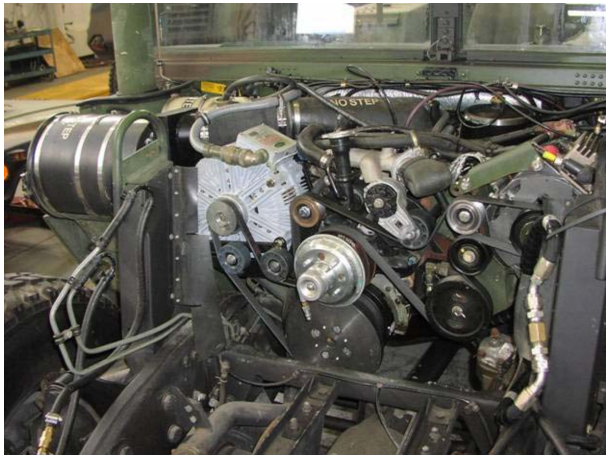
Engine main journal bearing side load (vector sum of A and C)



Bearing side load and crankshaft Woodruff key torque are serious HMMWV engine constraints

Potential solutions

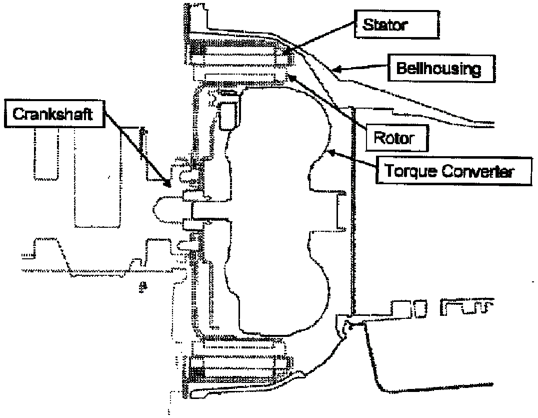
Dual belt driven HV generator



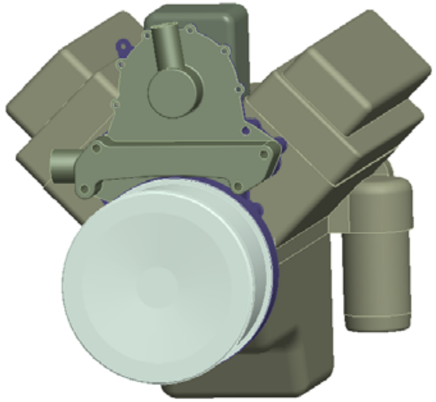
Alternator + belt driven HV generator

Turbo alternator

Conventional 28VDC alternators



Flywheel ISG



Front crank mount ISG

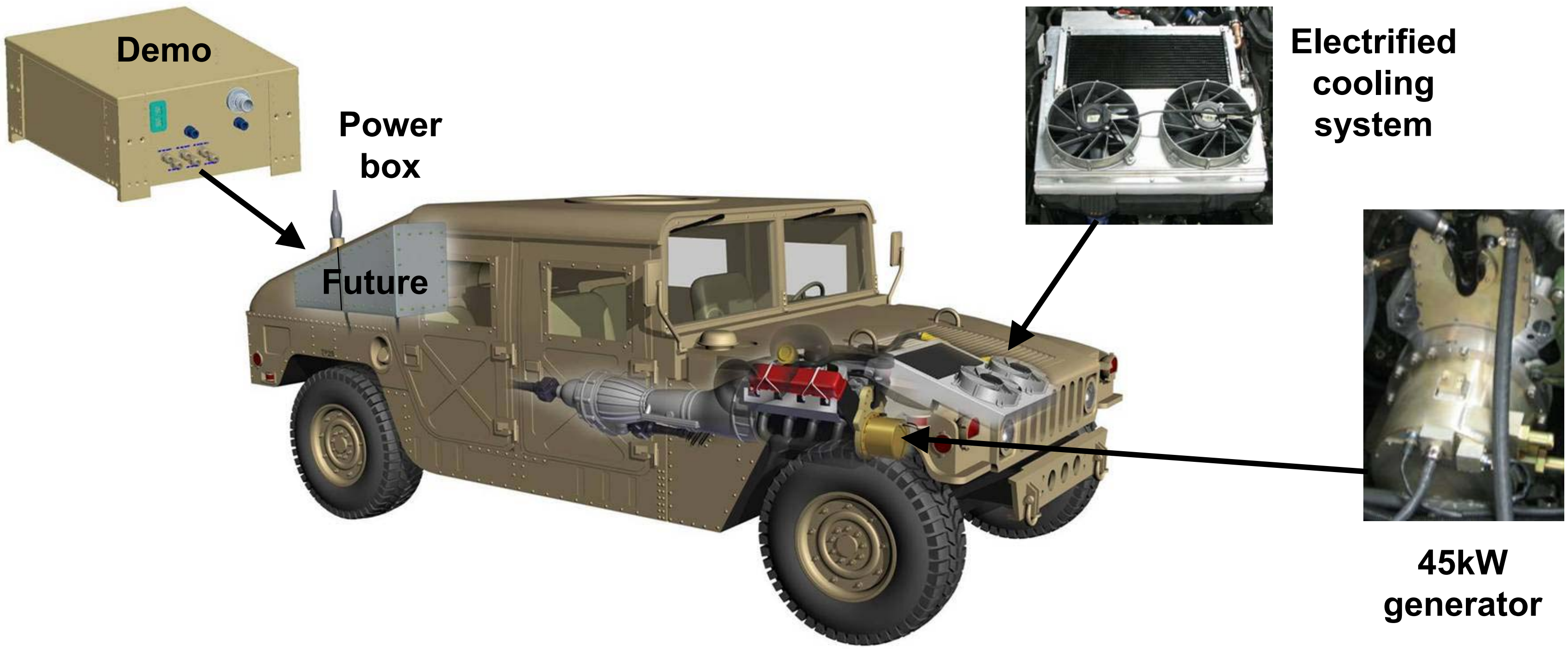
BAE SYSTEMS

Solution comparison

- Single and dual belt driven high voltage generators
  - \+ COTS solution, easy to install, low cost
  - − Won’t make full 400 amps 28VDC at idle, belt drive issues
- Turbo alternator
  - \+ Small, lightweight, easy to install
  - − Will not make power at idle, high risk approach
- Conventional 28VDC alternators
  - \+ Easy to install, low cost, mature technology
  - − Won’t make full 400 amps 28VDC at idle, belt drive issues, inefficient
- Flywheel integrated starter generator (ISG)
  - \+ Ideal solution for new vehicle designs
  - − Retrofit intrusive, requires transmission and torque converter removal / mod
- Front crank mount ISG
  - \+ Will make 400 amps 28VDC at idle, field retrofittable, efficient, robust
  - − Retrofit more complex than belt drive approaches

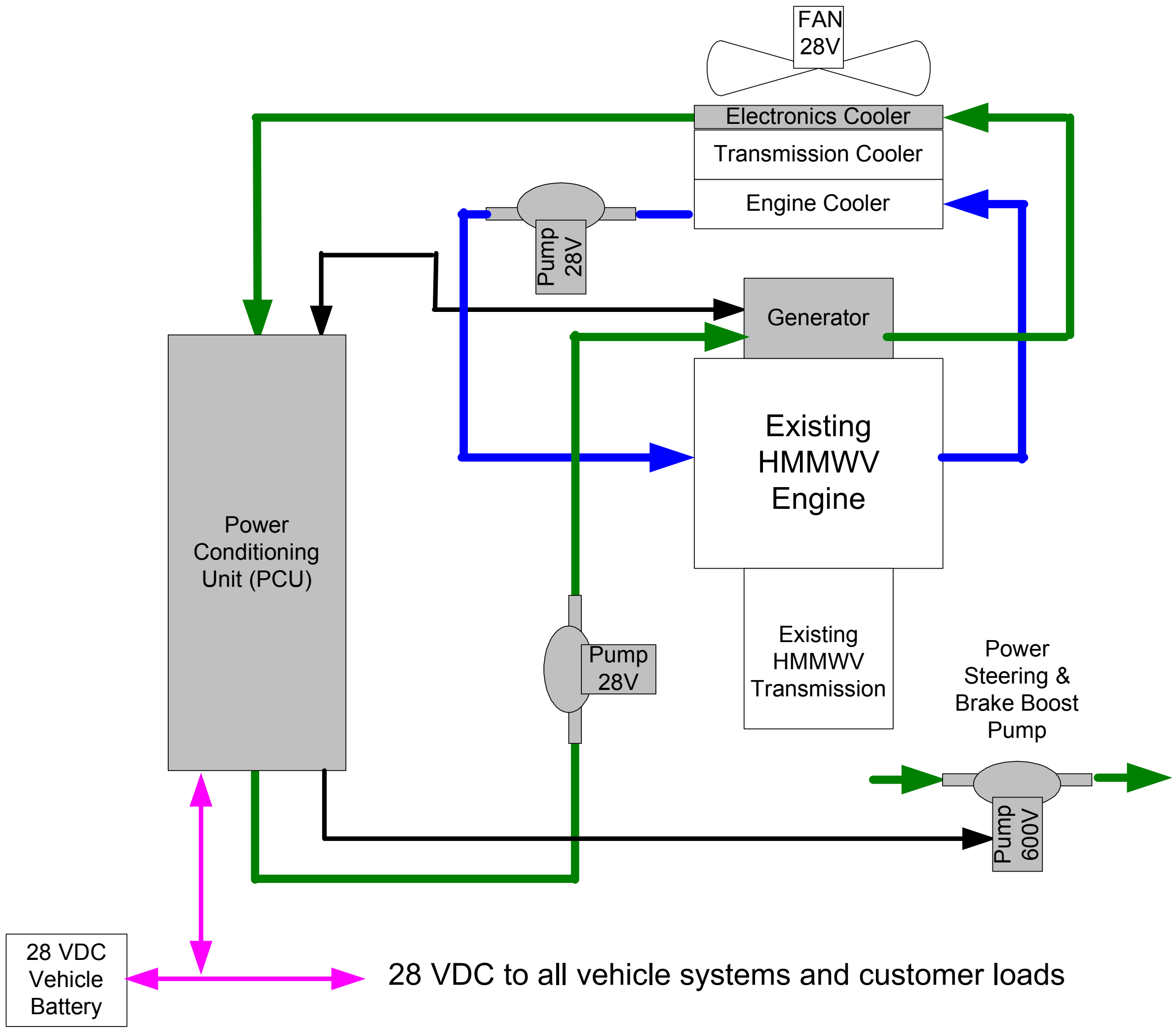
Front crank mount integrated starter generator (ISG) w/ electric accessories
Power-managed HMMWV

Power-managed HMMWV overview

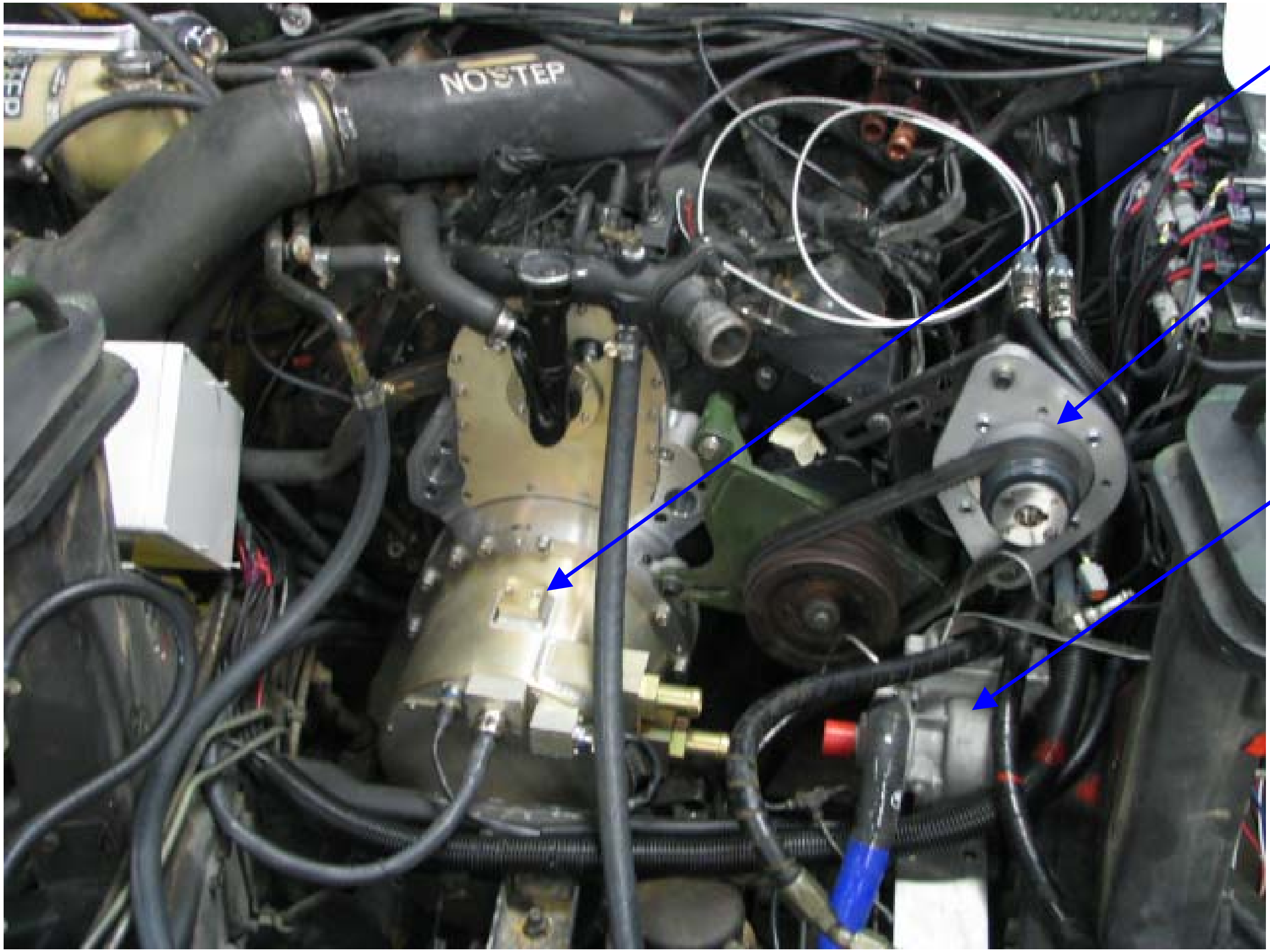


- Provides 400 amps of 28VDC power (11.2kW) over the entire engine operating range
- Provides 1kW 115VAC power (expandable to 30kW 230VAC power)
- Generator installs directly on engine crankshaft for high reliability and high power capability
- Automotive accessories are electrified for high efficiency and superior health monitoring
- Cooling system is electrified for superior engine cooling performance, even at low speeds

System architecture



Engine dress



ISG mounted on HMMWV engine crankshaft

Electric motor powering existing power steer pump

Generator and electronics cooling pump

HMMWV cooler stack removed for clarity

Cooler stack and electric accessories installation

Engine fan controllers (4)

Electronics and generator Cooler

Main cooling fans (two of 4)

Engine radiators

Engine water pump and controller

All engine accessories are power-managed

Demonstrator status

- Vehicle build complete
- 400 Amp power delivery and electric accessory functions verified
- Final integration and road testing in process
- Will be available for targeted customer demonstrations in May 2007

BAE SYSTEMS

Summary

- Satisfies urgent theater requirement for vehicle power
- Provides 400 amps of 28VDC over the entire engine operating range
- 30kW of clean 230VAC power may be added (as an option)
- May be installed in the field
- Space claim is compatible with HMMWV
- Will work on transmission PTO (for armored trucks)
- Improves HMMWV fuel consumption and system reliability
- Enhances HMMWV cooling system performance
- Flexible common modular power system (CMPS) architecture leverages FCS and ground combat vehicle developments

Electric Drive Approach to Mobile Power Platforms

Oshkosh Truck Corporation

Nader Nasr
Chief Engineer
Advanced Products Group

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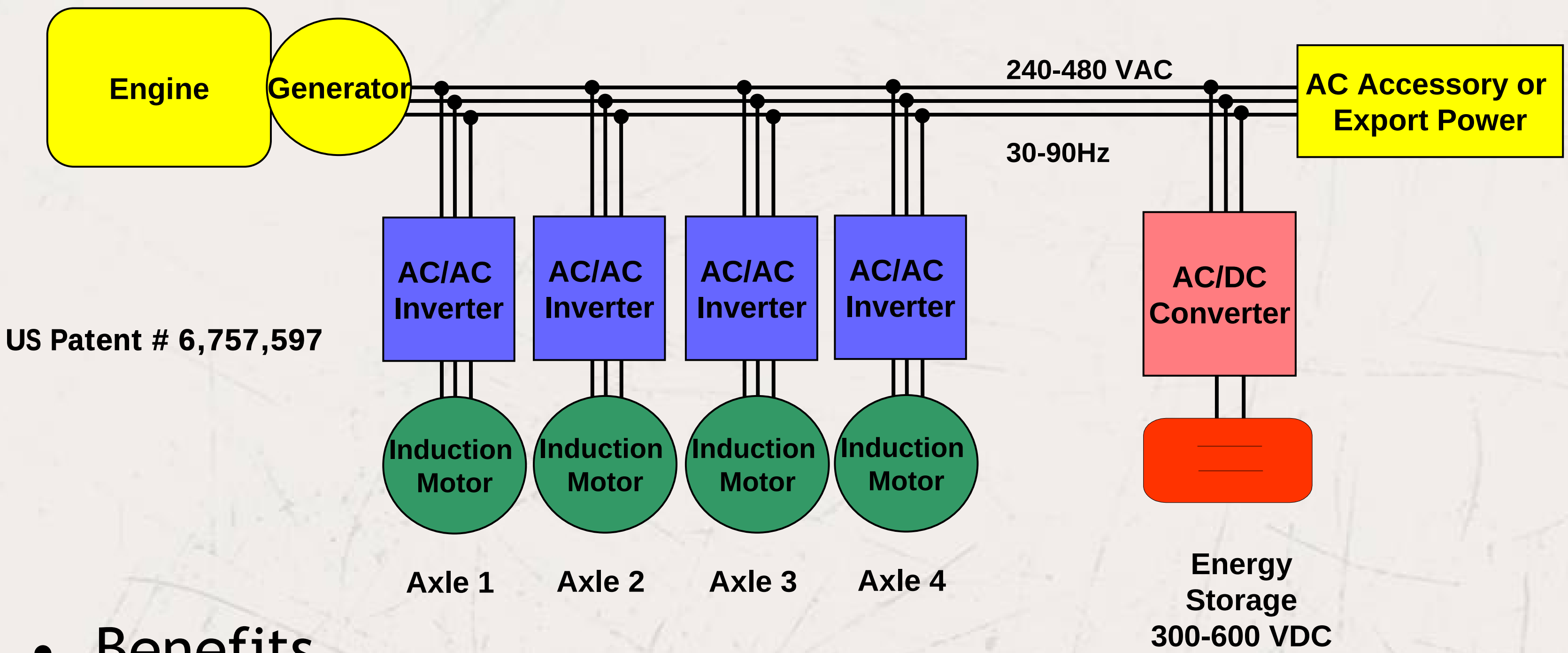
On Board Vehicle Power

Responding to military's needs for power in the theater

- Military Relevance
  - Increased mobility, power for onboard weapons
  - Back up power for mission critical equipment
  - Increased cargo space, reduced logistic footprint
  - Power options for early entry forces, high speed mobility

GET THERE FIRST

ProPulse® Electric Drive System



- Benefits
  - Large amounts of AC power available for export
  - Energy storage is an option
  - No batteries
  - Zero voltage maintenance
  - Improved fuel economy
  - Enhanced packaging flexibility

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HEMTT A3

- TACOM PM Heavy
- Improved fuel efficiency
- 100 kW Export power

MTVR OBVP

- ONR funded program
- 120 kW of export power
- Maintain vehicle performance

ProPulse® Implementation

Advanced Heavy Hybrid Propulsion System

- DOE / NREL 3 yr program
- Target 2x fuel economy
- Validation vehicle / Waste Management

Homeland Security

ARFF Applications

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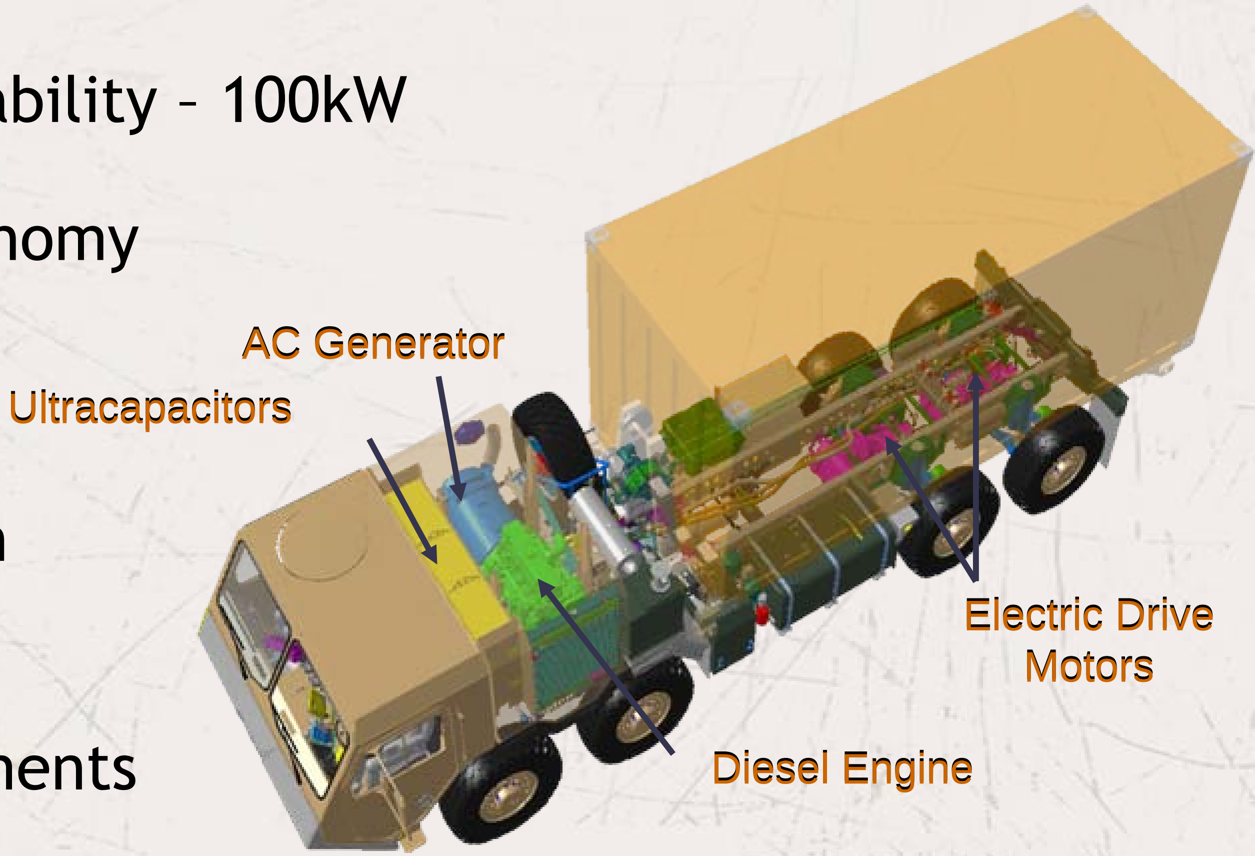
HEMTT A3

HEMTT A3

Program Primary Objectives

- Export Power Capability – 100kW
- Improved fuel economy
- Advanced Load Handling System light weight design
- Meet HEMTT objective requirements



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HEMTT A3
Key Technologies – Present

- Light weight modular design
- Diesel electric series hybrid
- Ultracapacitor Energy Storage
  – No batteries, life of vehicle design
- 100kW Exportable AC power
- Variable height independent suspension
- Multiplexed electrical system w/ advanced diagnostics
- C-130 unload capability
  – Enhanced Load Handling System (ELHS)

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Testing Completed

- 12K miles off road – Nevada
- Vehicle Performance testing
  – PSD Aberdeen
- Export Power Performance
  – PSD Aberdeen
- Fuel Economy >20% improvement

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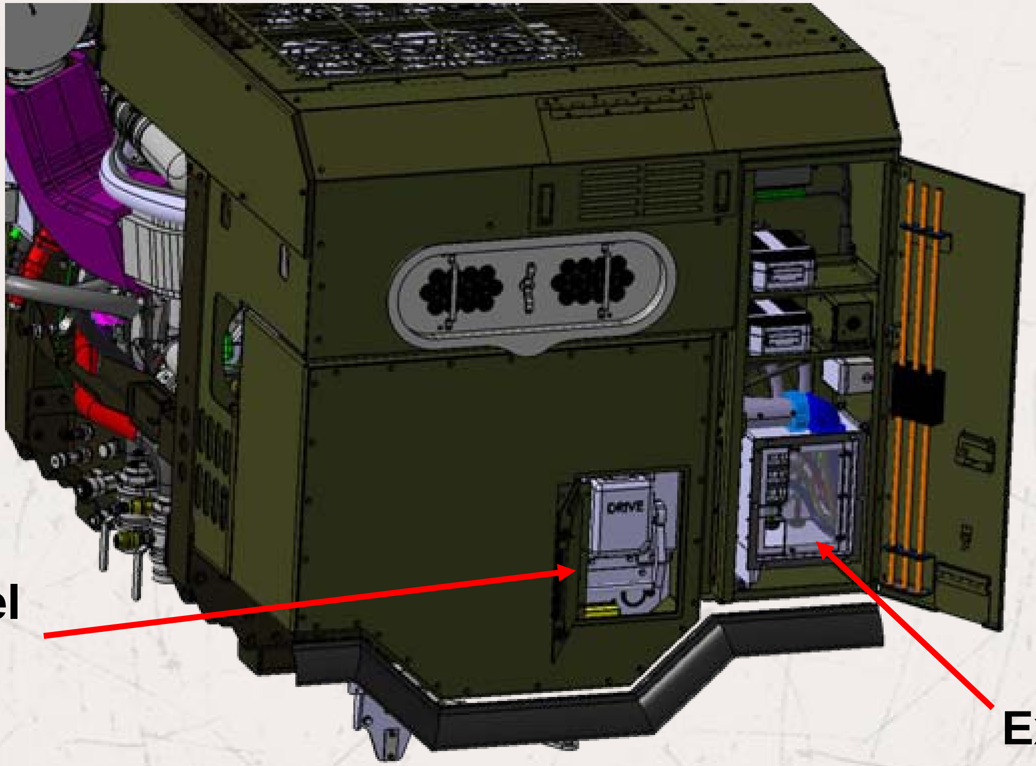
HEMTT A3 – Power Module



Reconnect Panel

Export Power Interface

Exportable Power:
100 kW @ 480 V or 240 V 60 Hz
86 kW @ 416 V or 208 V 50 Hz
86 kW @ 120 V 50 Hz or 60 Hz

Export Power Vehicle Interface Screens

Export Power Controlled From Inside Cab

- Adjustable voltage (primary voltage and fine adjustment)
- Adjustable frequency (primary frequency and fine adjustment)
- AC contactor on/off (turning on and off output power)

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Export Power

Platform System Demo, August 2006 Aberdeen Test Center

Tests Performed:

- Short Term Transient
  - Response MIL-STD-705C
  - Section 608.1
- Long Term Steady State
  - Stability MIL-STD-705C
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  - Section 601.4

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MTVR On-Board Vehicle Power
Office of Naval Research

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MTVR

- Performance
  - Oshkosh TK-4™ Independent Suspension
  - 70% Offroad Mission Profile
  - 7.1 ton payload cross country
  - 15 ton payload primary and secondary roads
- MTVR Based Variants
  - Cargo, Dump Truck, Wrecker, HIMARS Re-Supply Vehicle, Tractor, LHS (load handling system)

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MTVR OBVP Program – ONR Objectives

- Provide vehicle integrated power source
  - 120 kW of military grade export power
  - 21 kW of power on the move
- Easy retrofit of existing MTVR vehicle
- Use host vehicle's diesel engine for both mobility and power generation
- Retain MTVR performance
- Minimize weight
  - 25 lb / kW Threshold
  - 20 lb / kW Objective

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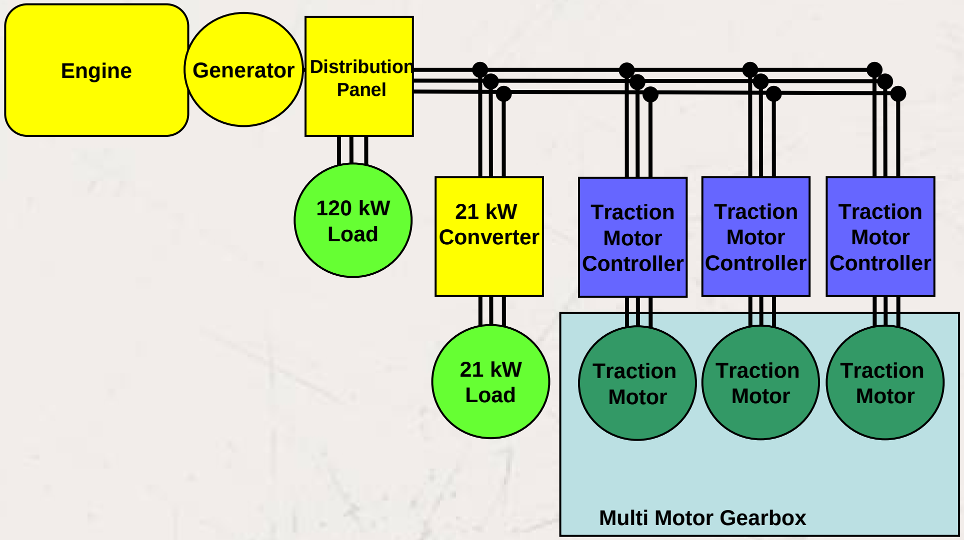
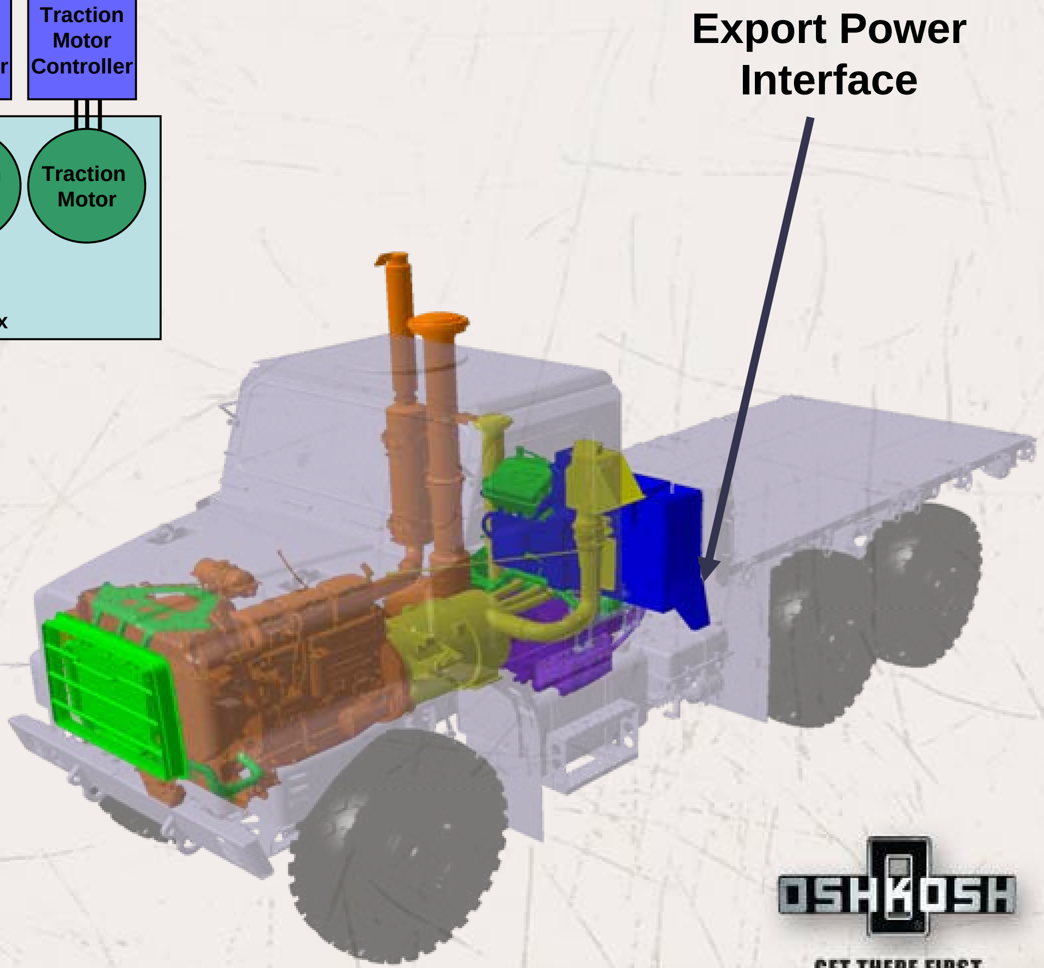
OBVP System Overview





- Pure diesel electric solution
- No Energy Storage
- Synchronous generator design

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OBVP Design

- 300 kW traction generator used for vehicle driving and providing stationary export power
- Synchronous generator design
  - Clean military grade power
  - No need for power electronics or conditioning
- Cab display is used to initiate switch over, voltage and frequency adjustments and diagnostics

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Export Power Performance

- 5 wire CAM style connection – Marine Corps request
- Meets requirements of tactical quiet generator
  - 120 kW of stationary export power
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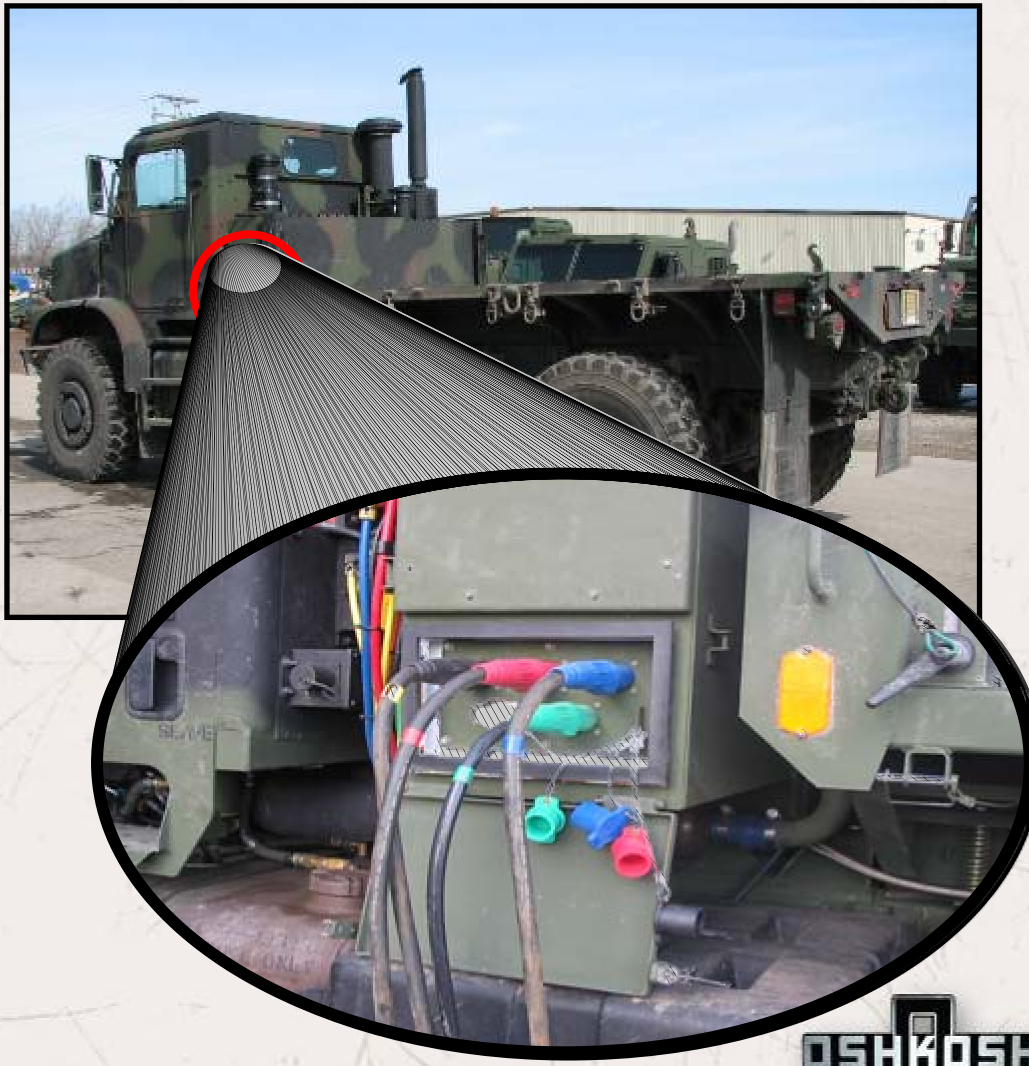
- Exceeds objective requirements, achieved 19 lb/kW



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Project Status

- OBVP build complete – January 2007
- Vehicle commissioning complete – March 2007
  - Basic driving functionality
  - 120kW stationary export power
- Deliver for Government durability testing – December 2007

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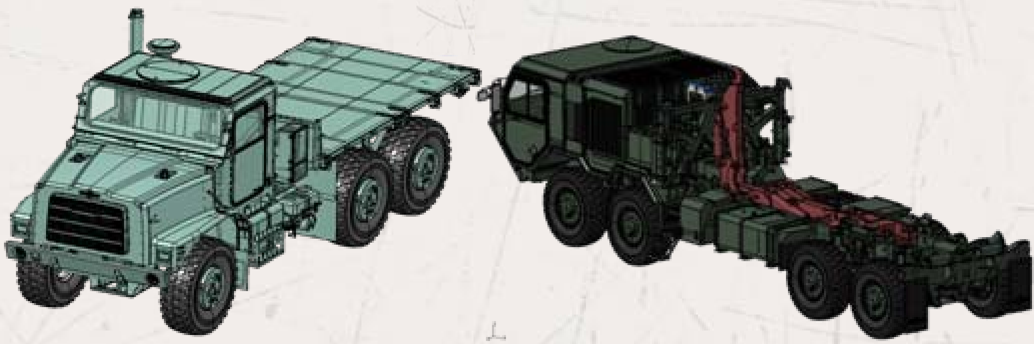
Summary

- Oshkosh's diesel electric technology presents a unique and superior solution for large mobile power requirements
  - lb/kW
  - $/kW
  - Power quality
  - No batteries



- Leverage developed ProPulse® system and components
- Provide simple wiring interface, and swift transition to exporting power

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Far Reaching Benefits

- Commercial
  - Improved MPG
  - Lower emissions
  - Packaging flexibility
  - Disaster relief
    - Export power 100 kW+
- Defense
  - Lower logistics burden
  - Export power
    - 100 kW+ Mil spec AC power
  - Higher performance
  - Increased functionality
  - Improved MPG

ProPulse® Technology Demonstrator – Katrina Support

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MEP Power Generation

Generation

Distribution

3 kW TQG
MEP – 831A
B0730

Commercial 25 kW
HMMWV Towable
Non-TQG
No TAMCN

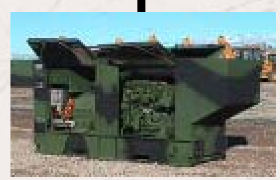
60 kW TQG
MEP – 806 A/B – 60 Hz
MEP – 816A – 400 Hz
B1021 / B1016

15, 30, & 100 kW
MEPDIS
B0595 / B0600 / B0605

2 kW MTG
MEP – 531A
New to USMC

10 kW TQG
MEP – 803A – 60 Hz
MEP – 813A – 400 Hz
B0891 / B0921

30 kW TQG
MEP – 805 A/B – 60 Hz
MEP – 815A – 400 Hz
B0953 / B0971



100 kW Mil-Std
MEP – 007A/B/C
B1045 / B1046

100 kW TQG
MEP – 807A
Fielding in FY06

120 kW
Mil-Std
MTVR OBVP

100 kW Mil-Std
HEMTT A3 Option

Your Questions

Export Power Developments

2007 Joint Service Power Expo

26 April 2007

Presenter: **Tom Trzaska**
Manager, Advanced Programs
GDLS Muskegon Technical Center
Muskegon, Michigan

Agenda

- Background
- Technical Objectives
- System Design
- Performance Testing
- Durability Testing
- Future Developments

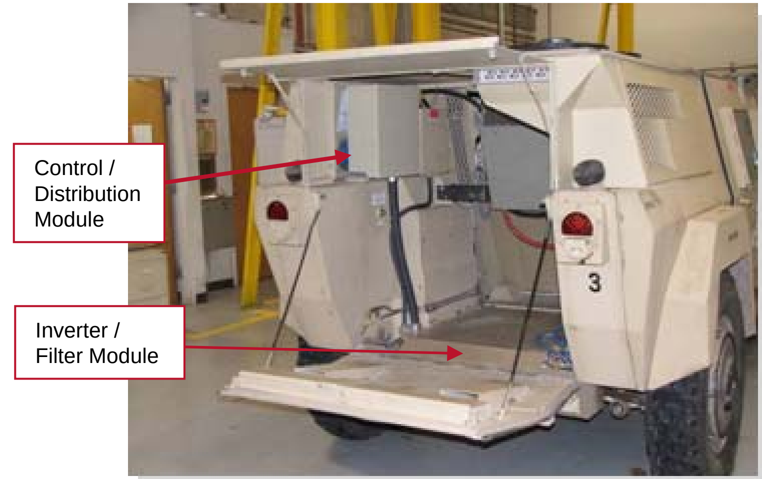
Background

- **GDLS and Magnet Motor GmbH Collaboration**
- **Robust Power Electronics Solutions**
  - **Electric Drive**
  - **Power Conditioning**
  - **Power Generation**
- **High Power Densities**
  - **Inverters to 13.75 kW/L**
  - **Bi-Directional DC/DC to 32.5 kW/L**

Power Generation and Management Experience

30 kW Export Power Unit

- Developed Under RST-V Program and GDLS Funding
- Provide Power to UOC and Fire Finder Radar
- Goal to Provide Similar Capability to 805 and 813 Gensets
- Exploit Inherent Power Generation Capability of Series Electric Drive



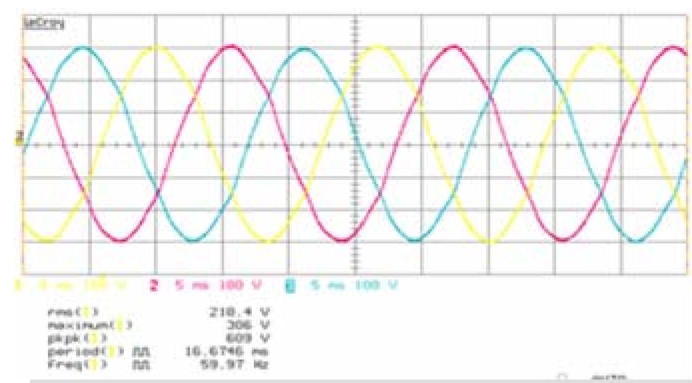
Unit Installed on USMC/ONR/DARPA RST-V

Replaced in Expeditionary Roles

Technical Objectives

- **Provide AC Power:**
  - **30kW 0.8Pf @ 60 Hz**
  - **10kW 0.8Pf @ 400 Hz**
  - **208/120VAC 3Φ, 4 wire**
  - **Mil Std 1332 Class 2A/B**
- **Synchronize and Load Transfer**
- **131^{o}F Operating Temp**
- **IEC 309, 100 amp connections**

Targeted Applications



Output Voltage Waveform

GENERAL DYNAMICS
Land Systems

Public Release Approval Pending
Case #xxxxxx

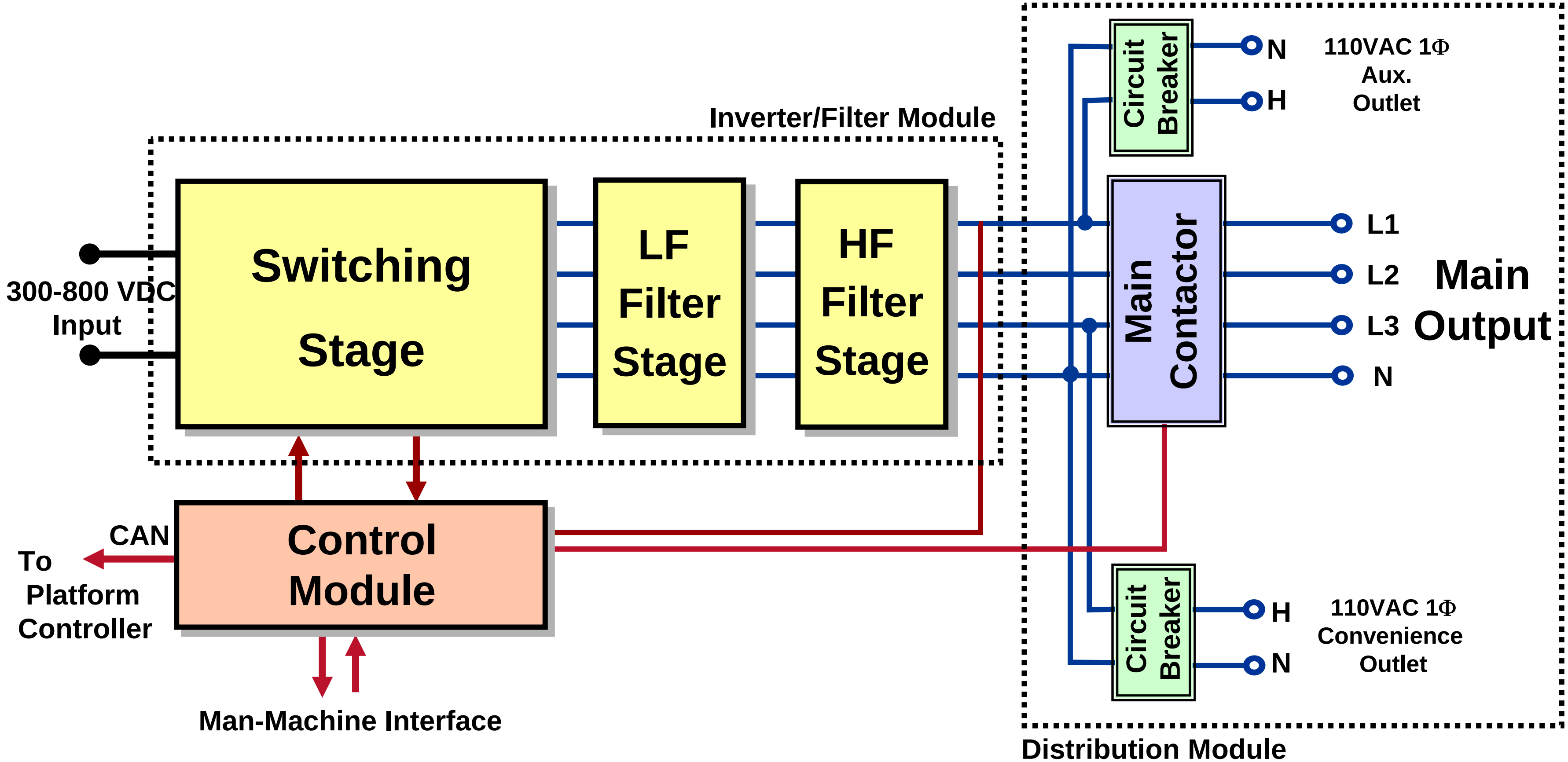
System Description

- High Density Solid State DC/AC Inverter System
- Commercial IGBT Based
- PWM Waveform Synthesis
- Three Modules for Adaptable Integration
- Dual Frequency Capability
- Water Cooled Inverter/Filter
- Growth to 50hz and 240/416 VAC output

ACC04 30 kW Inverter / Filter Unit

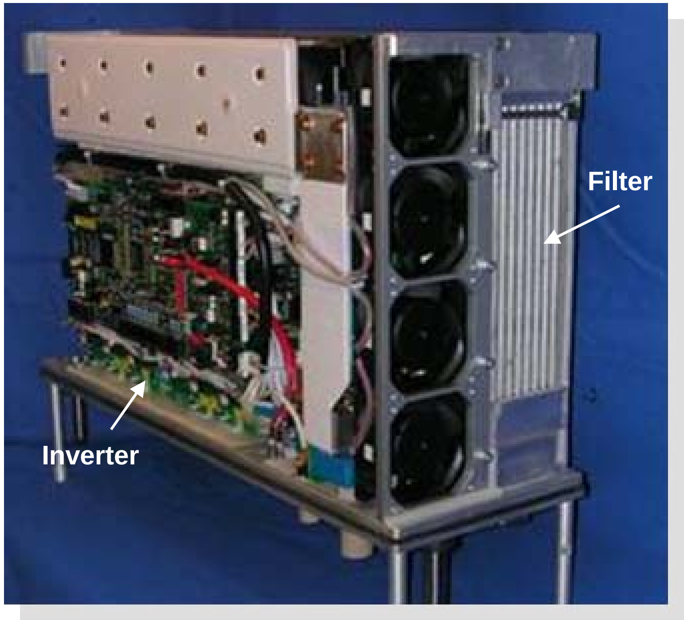
Interface and Control Panel

System Block Diagram



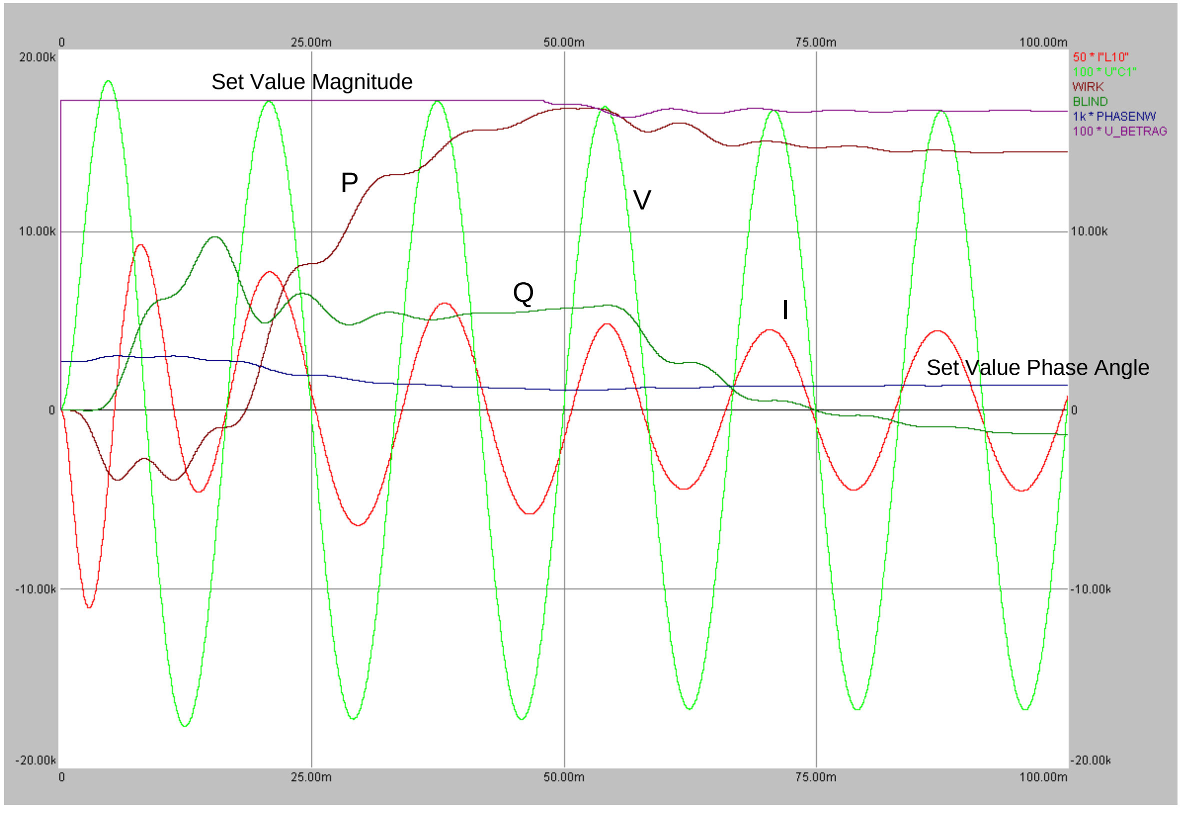
Summary Specifications

- **System Characteristics:**
  - Input Voltage 300-800 VDC
  - Output: 120 / 208 VAC
  - Dual Frequency 60 / 400 Hz
  - WPG Cooled (10 l/min @ 70 °C)
  - Weight 110 kg
  - Volume 85Liters
  - Voltage Regulation <2%
  - Frequency Regulation <1%



30 kW Inverter/ Filter Module

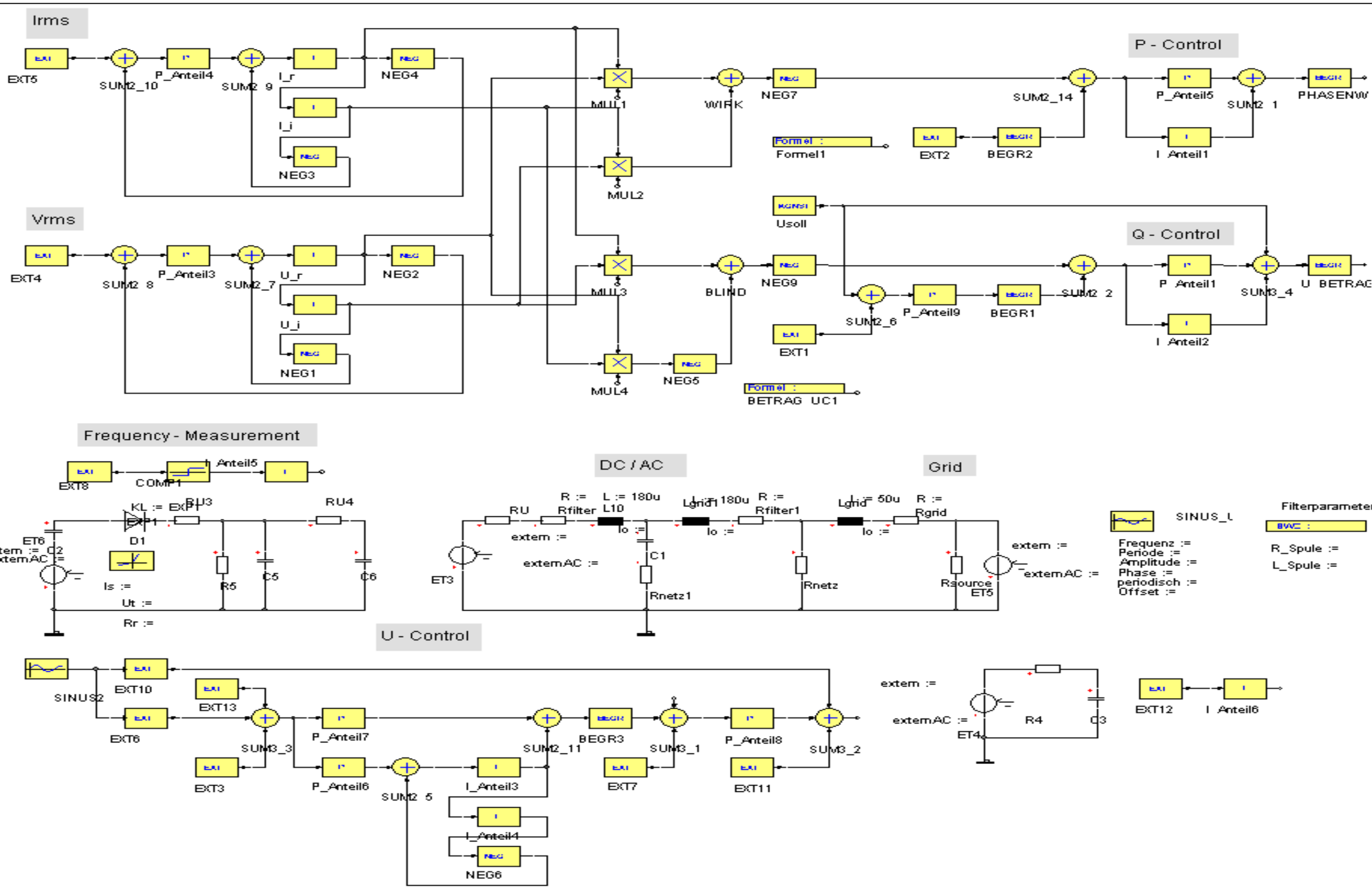
Performance Predictions



Simulation of Synchronization Process to a Grid -> Stabilization within 75 msec

- **Full Circuit and Control Model Refined and Validated through Lab and Field Testing**

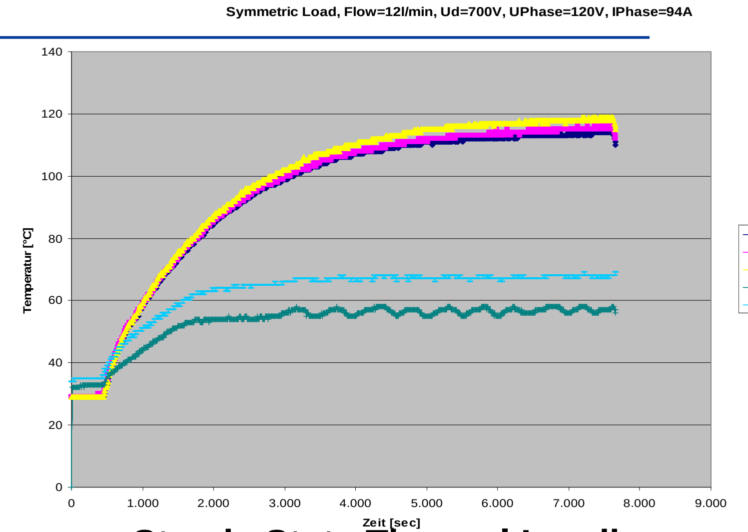
Performance Predictions



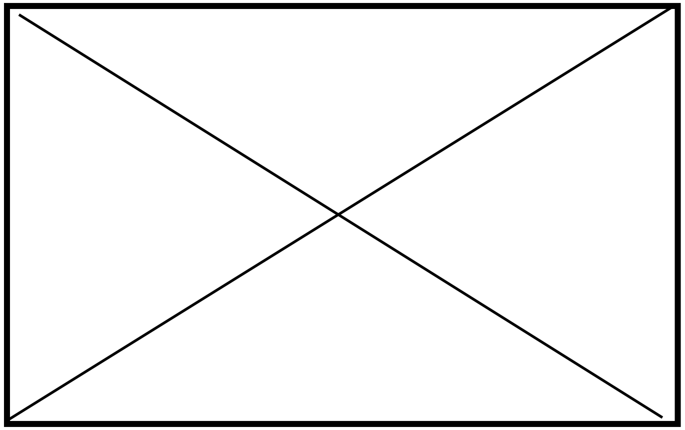
- **Synchronization Control Model**

Performance Testing

- **Full Series of development bench tests completed at Magnet Motor**
- **On Vehicle Lab Testing**
  - ↗ **Inverter / Vehicle Control Tuning**
  - ↗ **Power Quality**
  - ↗ **Load Cycling: Step Apply and Load Dump**
  - ↗ **Inductive Load Start**
  - ↗ **Short Circuit**



Steady State Thermal Loading



Step Load

GENERAL DYNAMICS
Land Systems

Public Release Approval Pending
Case #xxxxxx

Field & Durability Testing

- Durability Testing
  - Mixed Course Durability
  - 2 hour Export Power Cycles Every 100 Miles
  - Over 275 hours operation
  - Reliability Database established
- Technical & Durability Testing at APG
  - 705 Testing
  - EMC
  - Durability Cycles

RST-V with Export Power Units

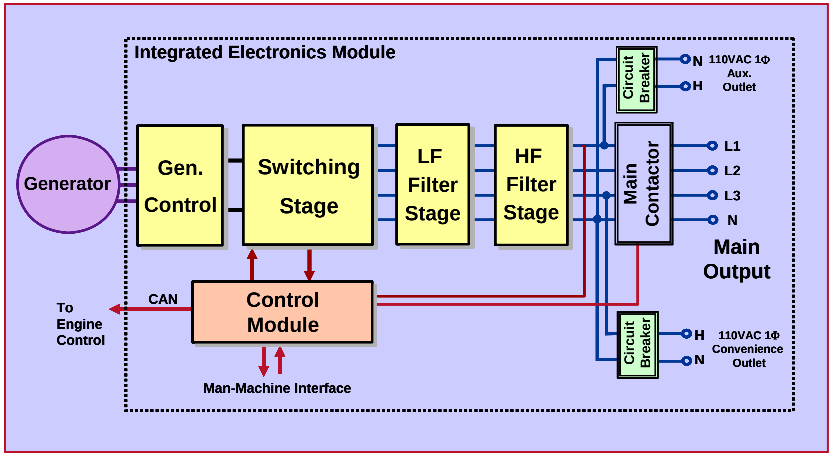
Durability Load Test

Current Developments

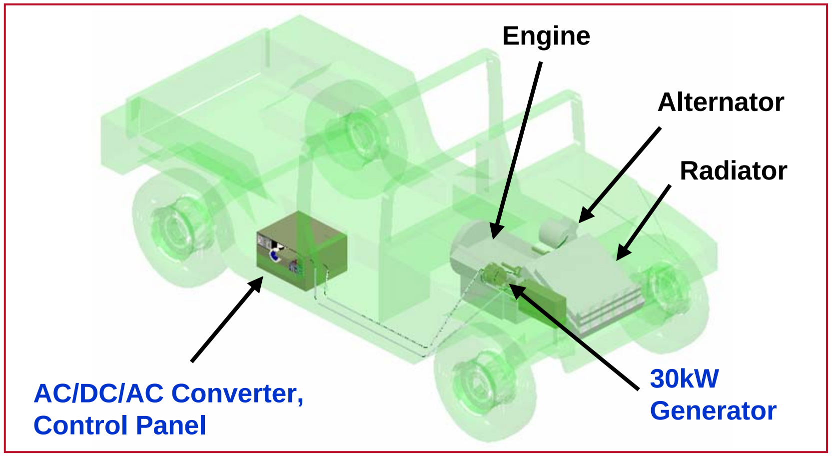
- **RST-V System Upgrades Under Development**
  - **High Frequency Filtering**
  - **Voltage Measurement**
  - **Control Loop Calibration For High Power Factor Operation**
  - **Refinement Of Fault Detection Algorithm To Improve Motor Start Capability**

Current Developments

- Current System Being Applied To HMMWV
- Core Electronics, Software Repackaged
- High Density PM Generator Added To Provide Power Generation
- Low Impact 20/30 kW Retrofit Kit



Block Diagram



20/30 kW Export Power Concept

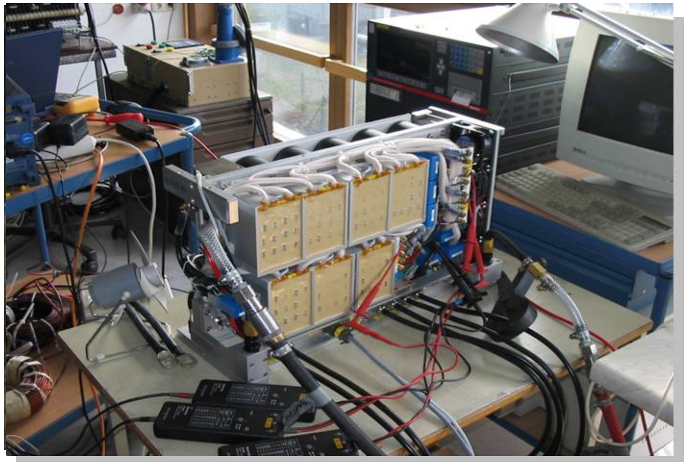
Current Developments (Cont.)

- **Initiating Portability Study to Other Platforms**
- **Initial Focus on Select MRAP Candidates**
- **Scope of Effort:**
  - **Develop BTA Installation concept for each platform**
  - **Design Mod Kit including installation hardware**

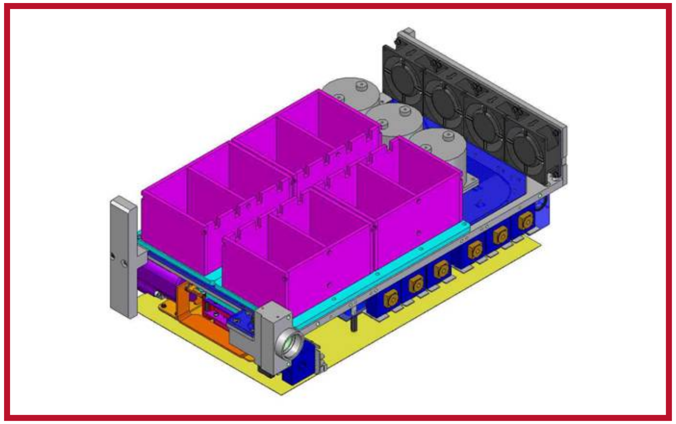
Portability Study Candidates

Summary

- GDLS / Magnet Motor Team Has Demonstrated 30kw Export Power System
- High Density System Reduces Impact To Host Vehicle
- Extending And Refining Design For Portable Application To Wide Range Of Vehicles



Current Generation Remains in Test



Future Electronics Assembly

On-Board Vehicle Power

Joint Service Power Exposition

25 April 2007

Briefings

- **Oshkosh Truck Corporation**
  - Nadr Nasr
  - Oshkosh Truck’s Electric Drive approach to Mobile Power Platforms
- **ePower LLC**
  - William Henrickson
  - 30 kW On-Board Vehicle Power for the HMMWV
- **General Dynamics Land Systems**
  - Tom Trzaska
  - On-Board Vehicle Power for the HMMWV and MRAP
- **BAE Systems**
  - Stephen Cortese
  - Power Management and Mission Capability Integration for HMMWV

Electric Drive Approach to Mobile Power Platforms

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On Board Vehicle Power

Responding to military's needs for power in the theater

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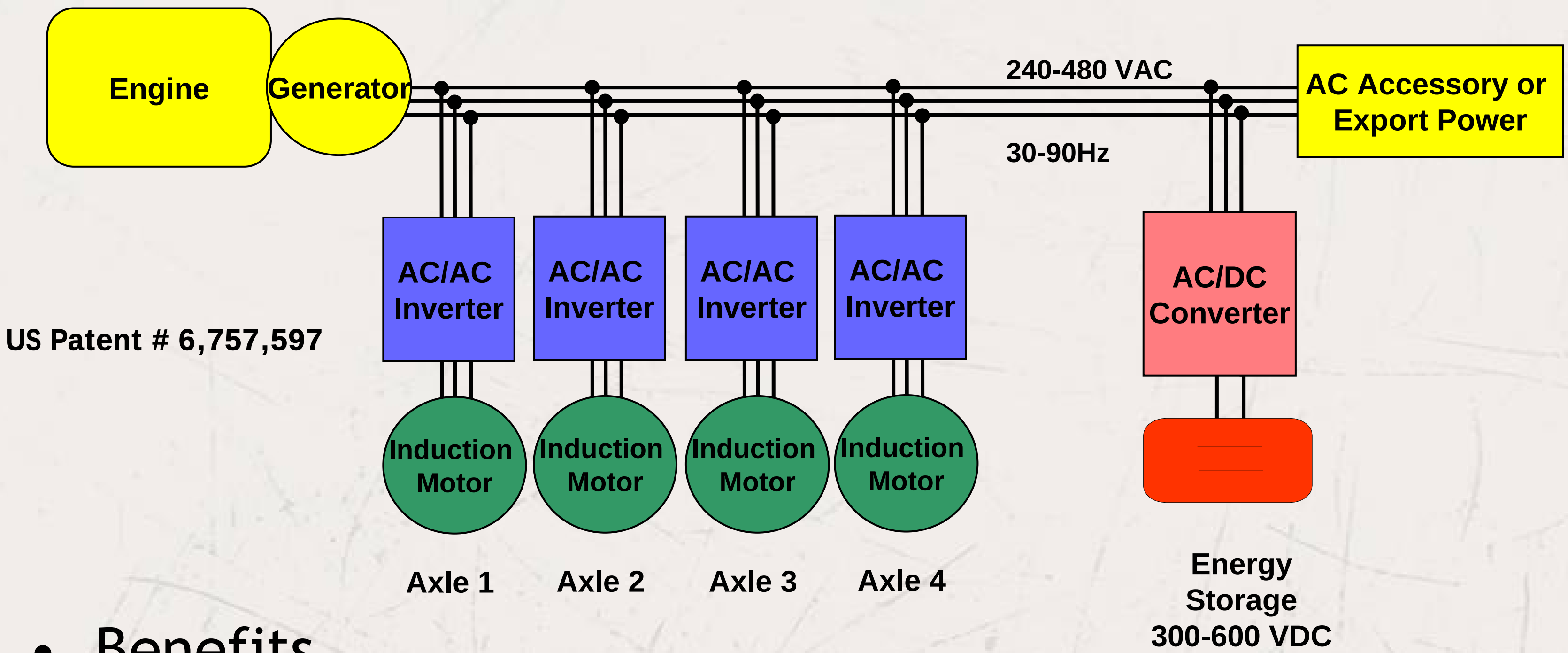
ProPulse® Electric Drive System



- Benefits
  - Large amounts of AC power available for export
  - Energy storage is an option
  - No batteries
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HEMTT A3

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Homeland Security

ARFF Applications

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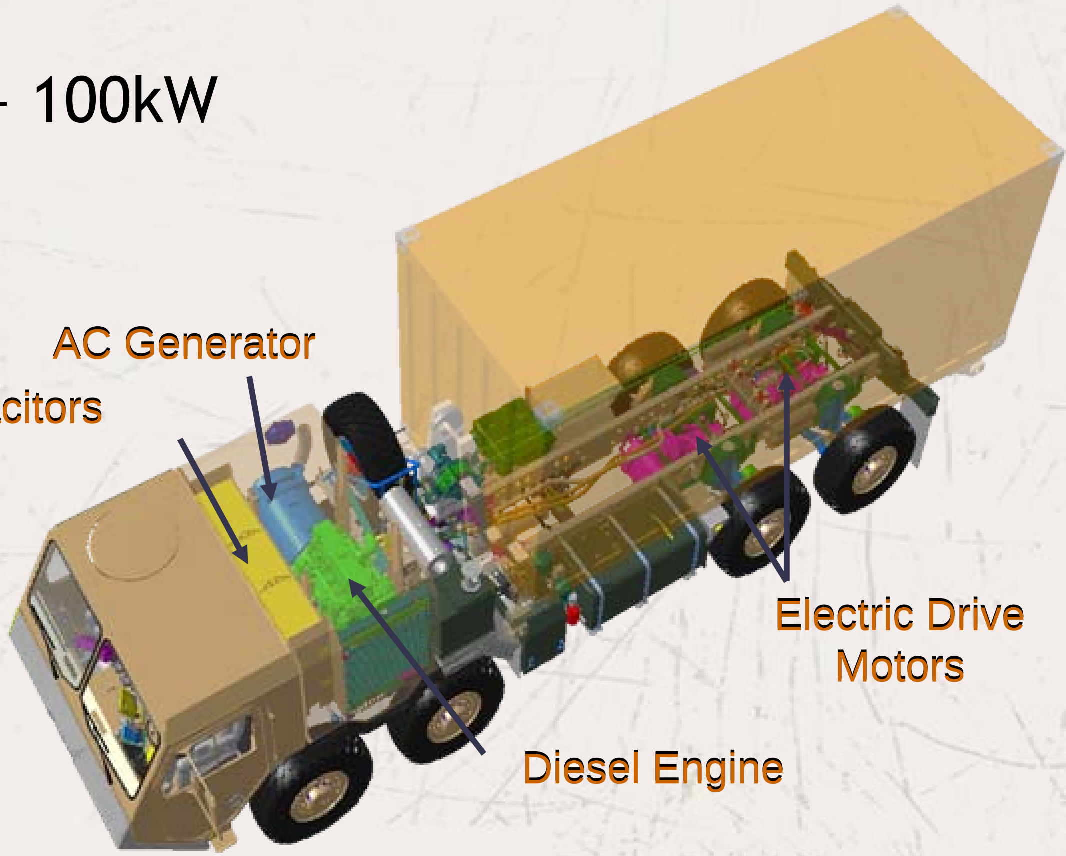
HEMTT A3

HEMTT A3

Program Primary Objectives

- Export Power Capability – 100kW
- Improved fuel economy
- Advanced Load Handling System light weight design
- Meet HEMTT objective requirements



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HEMTT A3
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HEMTT A3

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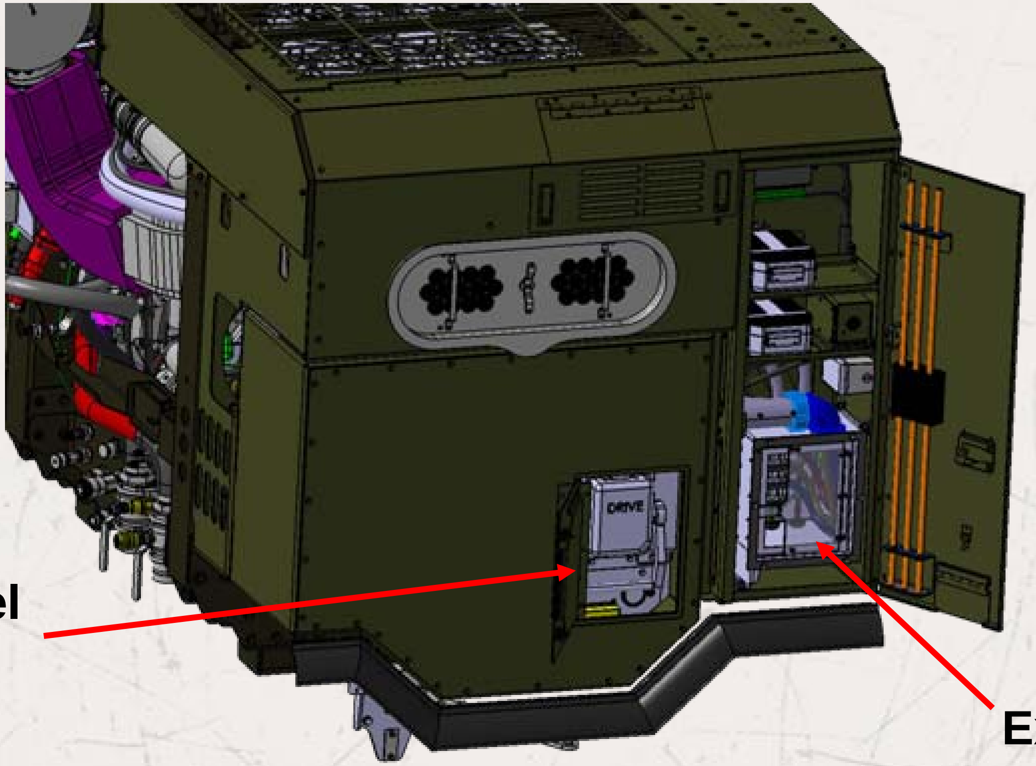
HEMTT A3 – Power Module



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MTVR On-Board Vehicle Power
Office of Naval Research
BAA – 04 – 011

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MTVR

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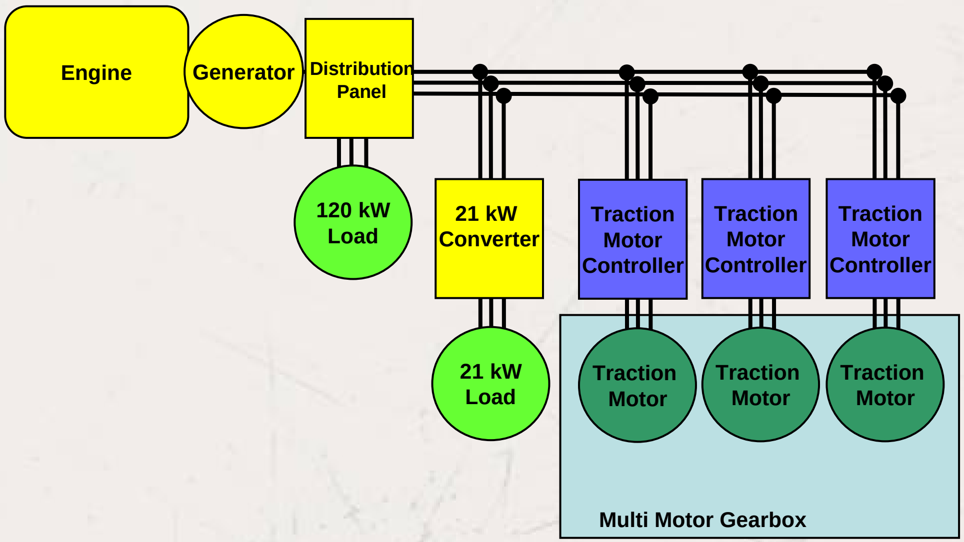
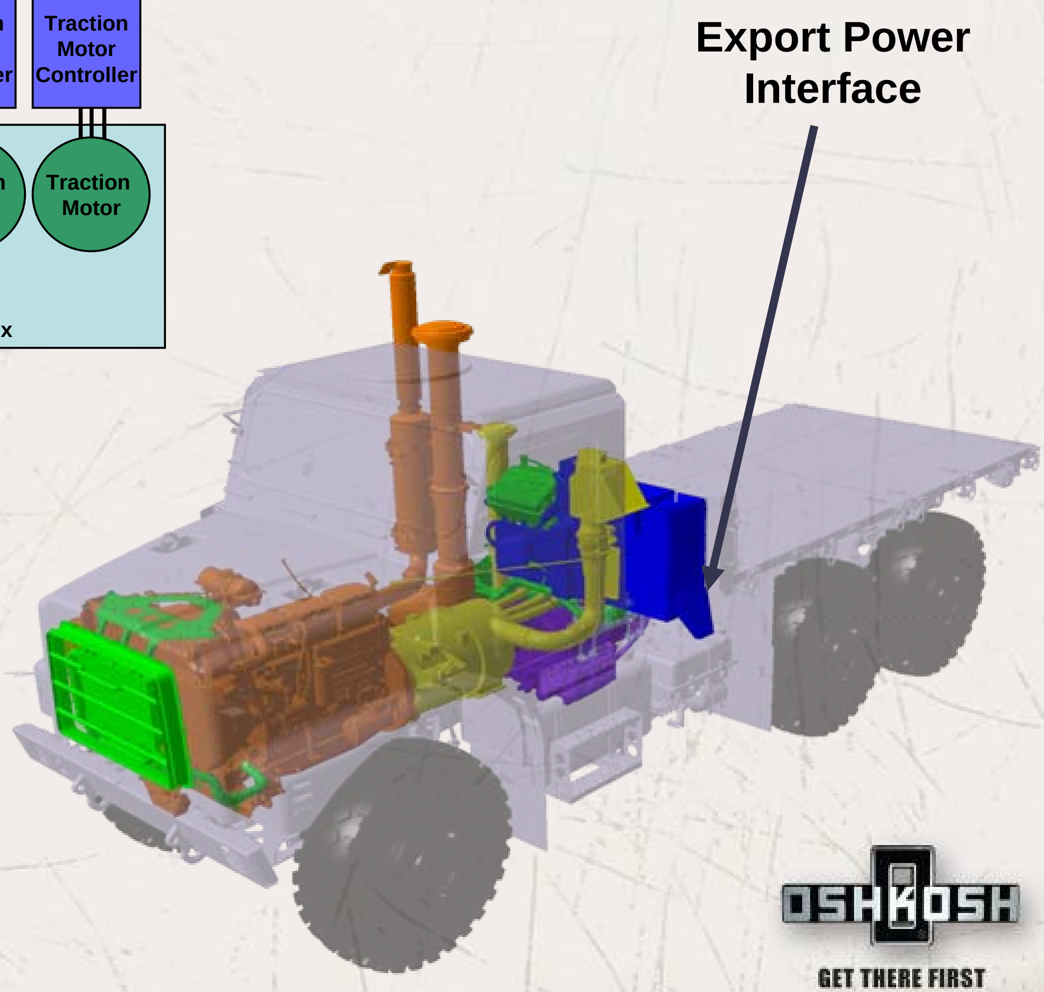
OBVP System Overview



- Pure diesel electric solution
- No Energy Storage
- Synchronous generator design



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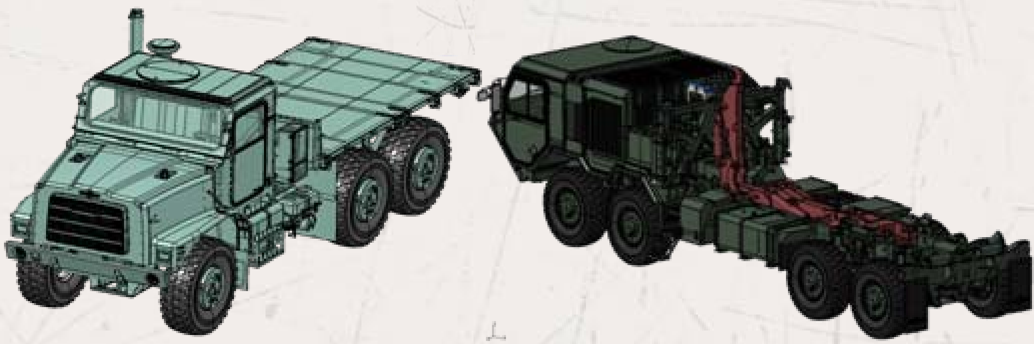

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OSHKOSH GET THERE FIRST

Far Reaching Benefits

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- Defense
  - Lower logistics burden
  - Export power
    - 100 kW+ Mil spec AC power
  - Higher performance
  - Increased functionality
  - Improved MPG

ProPulse® Technology Demonstrator – Katrina Support

OSHKOSH
GET THERE FIRST

MEP Power Generation

Generation

Distribution

3 kW TQG
MEP – 831A
B0730

Commercial 25 kW
HMMWV Towable
Non-TQG
No TAMCN

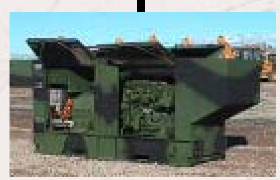
60 kW TQG
MEP – 806 A/B – 60 Hz
MEP – 816A – 400 Hz
B1021 / B1016

15, 30, & 100 kW
MEPDIS
B0595 / B0600 / B0605

2 kW MTG
MEP – 531A
New to USMC

10 kW TQG
MEP – 803A – 60 Hz
MEP – 813A – 400 Hz
B0891 / B0921

30 kW TQG
MEP – 805 A/B – 60 Hz
MEP – 815A – 400 Hz
B0953 / B0971



100 kW Mil-Std
MEP – 007A/B/C
B1045 / B1046

100 kW TQG
MEP – 807A
Fielding in FY06

120 kW
Mil-Std
MTVR OBVP

100 kW Mil-Std
HEMTT A3 Option

Your Questions

OSHKOSH

GET THERE FIRST

Workshop

Battery Technical Manuals and Milspecs

Susan M. Waggoner
Electronics Engineer
Code 6095, Bldg. 3287W
300 Highway 361
Crane, IN 47522-5001
Phone 812-854-4103, DSN 482-4103
Fax 812-854-1212
susan.waggoner@navy.mil

- **Update**
- **Comments**
- **Q&A**

- **Technical Manuals**
- **Milspecs**
- **Batteries**
- **Battery chargers**


Tactical
Solar Power
Systems
Presented by:
NEST Energy Systems Inc.
Prescott, AZ
Tom Lederle
VP Product Development

Tactical
Solar Power Systems

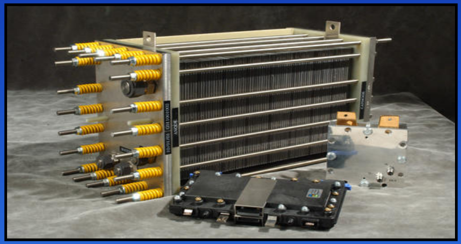
- Types of electrical power sources
- What’s wrong with what we have now?
- If we had our druthers
- What’s deliverable TODAY

TACTICAL ENERGY SOURCES

Generators

Batteries

Fuel Cells



Solar

Why bother with renewable energy?

COST OF FUEL IN FORWARD AREAS

Depreciation	$1.5M	8%
Maintenance	$1.5M	8%
Fuel	$7.9M	43%
Support personnel	$6.3M	35%
Transport on battlefield	$0.1M	
Transport to battlefield	$0.8M	
TOTAL COST	$18.1M	

78%

Total KWH capacity 6,031,200 KWH (5600 hrs x 1077KW)

Cost delivered in forward areas → $3.00/KWH

“State of the Art”

Currently, there is no clean, quiet, and “fuel-less” solution for supporting large electrical loads with highly portable units.

DRUTHERS MEET REALITY

A reasonable compromise

- Sustain 3kw load continuously for 12 hours <u>without harvesting or generation</u>
- Support a 3kw load continuously for 15 days <u>without intervention or refueling</u>
- Towable on an LTTHC trailer behind a HMMWV <u>over any terrain</u>
- Ready for <u>real-world deployment</u> ASAP

Raven LTSU

Lightweight Towable Solar Unit

- Hybrid design uses onboard automatic genset
- Uses <u>much</u> less fuel than genset alone
- Easy to set up
- Immediate electrical power
- At Technology Readiness Level 6 ***now***

Reduces fuel usage by *nearly half*

Raven LTSU

Lightweight Towable Solar Unit

LTSU vs genset-only, 15 day mission

Solar Gain and Fuel Consumption					
	GENSET	ONLY		4.8 kw	LTSU
Continuous load	3.0	kw		3.0	kw
Total kwh/day	72.0	kwh		72.0	kwh
Total kwh 15 days	1080.0	kwh		1080.0	kwh
Insolation factor				6.0	
Solar collection		kw		4.8	kw
Solar gain / day		kwh		28.8	kwh
Solar gain 15 days		kwh		432.0	kwh
% of load by solar	0%			40%	
Accumulated kwh deficit	1080.0	kwh		648.0	
Less stored energy				40.0	kwh
Genset size	3.0	kw		3.0	kw
Genset fuel usage	0.33	hr		0.33	hr
Genset run time	360.0	hrs		202.7	hrs
Fuel used 15 days	118.8	gal		66.9	gal
Weight of jp8 / lb	6.42			6.42	
Weight of fuel	762.7	lbs		429.4	lbs
Weight of genset	326.0	lbs		326.0	lbs

WEIGHT	
Container	700
Battery pack	890
Inverter, etc	100
Rack 3 x 24 foot truss	260
Panels 24 * 45# ea	1080
Genset (2kw diesel)	326
Fuel	429
TOTAL	3785

Raven LTSU
Lightweight Towable Solar Unit

- **Total weight 3800#**
- **3kw for 15 days without intervention**
- **3kw for 12 hours without generation or harvesting**
- **Droppable, flyable, etc.**
- **Literally bulletproof**

Large Scale Renewable Energy Production

LARGE SCALE RENEWABLE ENERGY PRODUCTION

NEST Transportable Solar Grid

- Arranged in “clusters” of 10-12 units (100kw+)
- For longer term requirements (6months+)
- All-up cost, less than $1 per KWH in forward area

LARGE SCALE RENEWABLE ENERGY PRODUCTION

NEST Transportable Solar Grid

- Deliverable by air, land and sea
- Clean, quiet power - no fuel required
- Power for force support areas
- Can be combined with genset for HYBRID operation

LARGE SCALE RENEWABLE ENERGY PRODUCTION

NEST Transportable Solar Grid

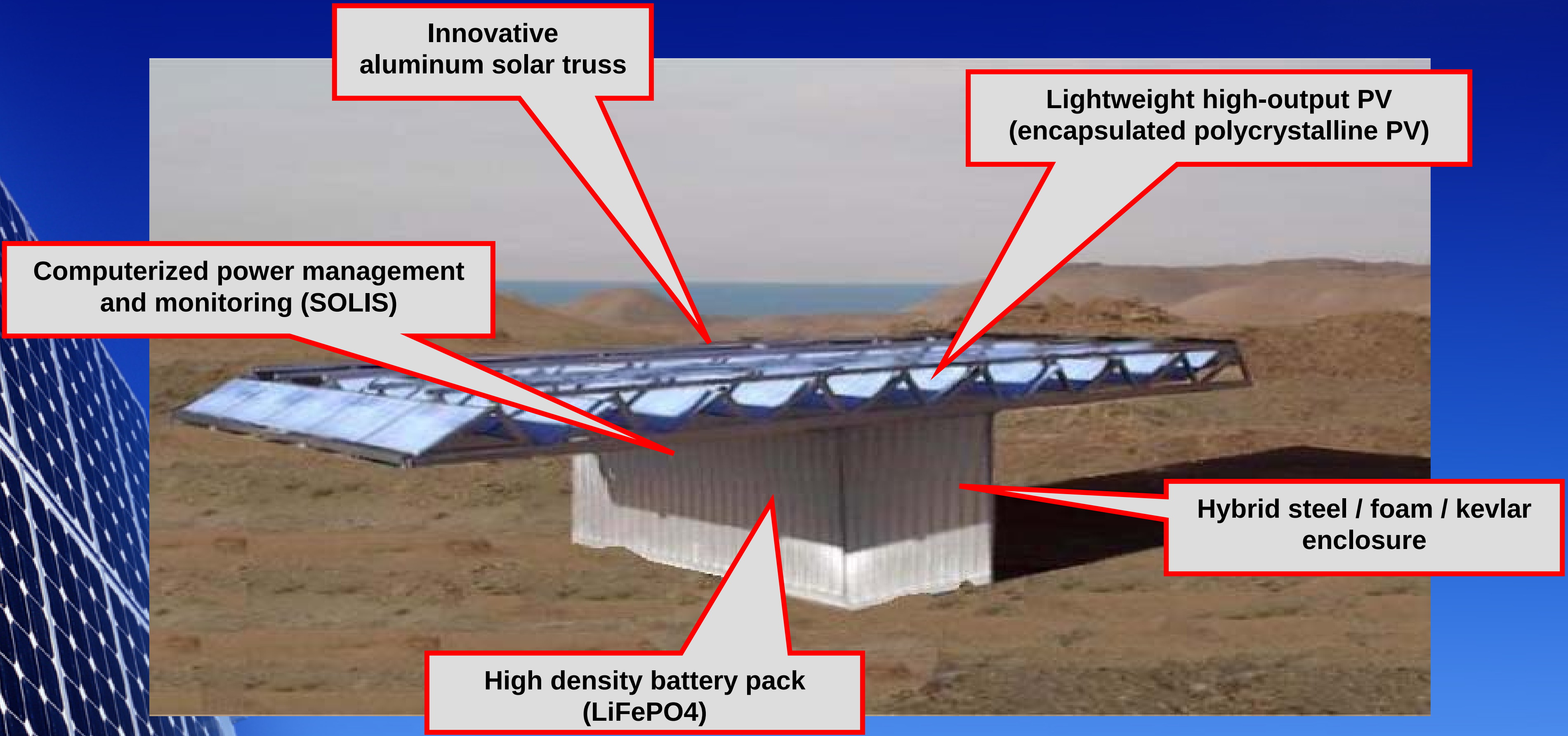
- Supports reconstruction projects
- Disaster relief shelters/housing
- Military base housing
- Remote, off-grid areas

Technological Advancements

Today and Tomorrow

Portable Renewable Energy Solutions

Enabling Technological Advancements



Portable Renewable Energy Solutions
Near Future (3-5 year) Developments

What's on tap…

- Solar panels with 40-50% efficiency (2 to 3 times current COTS)
- Solar panel will cost $1.50 per watt instead of $5.00 per watt
- Batteries ten times as weight-efficient as lead-acid

Portable Renewable Energy Solutions

Near Future Developments

If technology that's in the laboratory today were available tomorrow…

- **We could provide a portable, towable solar unit that would supply 100% of the DREAM energy needs <u>from solar alone</u>. No noise, no fuel, no maintenance.**

- **We could manufacture large-scale solar systems that could be transported on two medium size trucks and would replace a 100kw generator that burns 200 gallons of fuel per day.**

QUESTIONS / COMMENTS

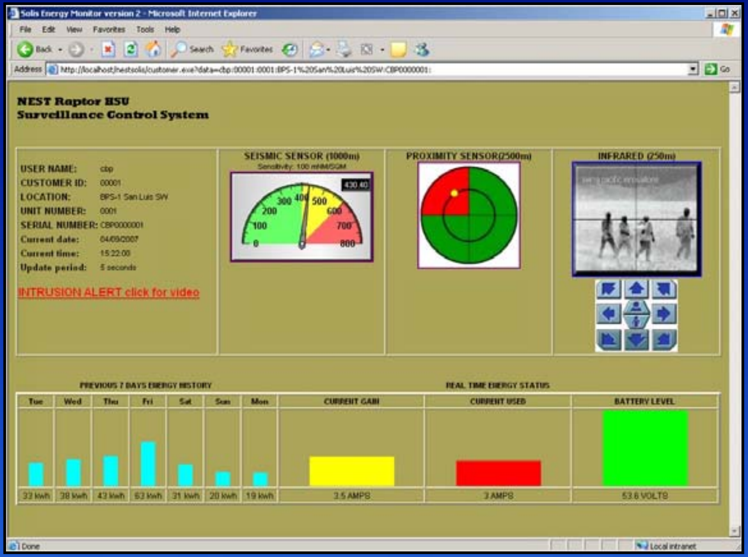
NEST Energy Systems Inc.
7500 W. Pasture Lane, Prescott, AZ
8367 E. Pecos Drive, Prescott Valley, AZ
(928) 460-2811
www.NestEnergySystems.com

GSA Advantage!
www.gsaAdvantage.gov

Portable Renewable Energy Solutions

Enabling Technological Advancements

SOLIS™ Energy Management and Security System

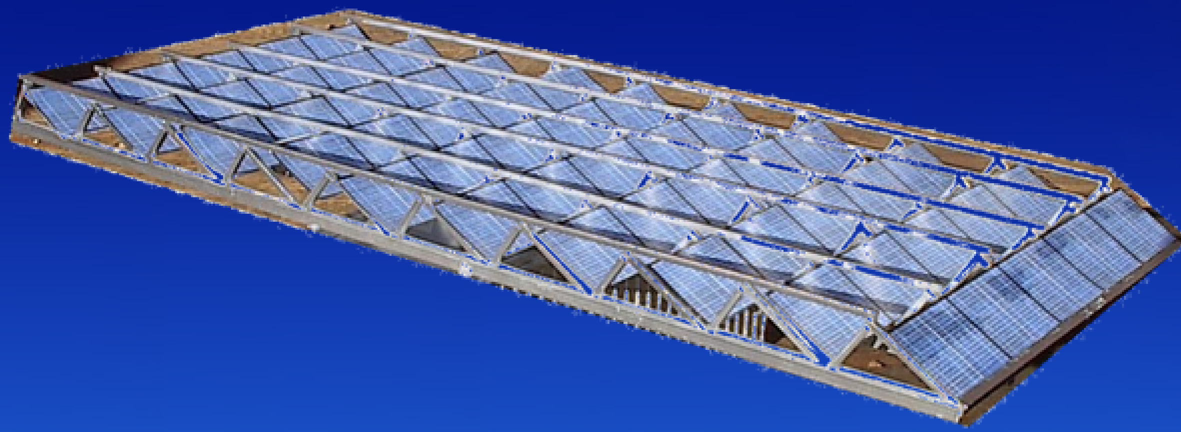


- Secure, web-based communications protocol
- Interactive communications between unit & HQ
- Alerts to power fluctuations / intruders
- Optional surveillance / security system

Portable Renewable Energy Solutions

Enabling Technological Advancements

Aluminum truss grid



- Patented “truss-rack” design
- Accelerates deployment of large-scale PV systems
- Support panels at correct angle
- Wind, torsion, shear, load tested
- 2 person set up, no special tools, expertise needed

Portable Renewable Energy Solutions

Enabling Technological Advancements

Hybrid steel / foam / Kevlar shell

- In production
- Strong as reinforced 14g steel shell
- Reduces enclosure weight from 1200# to 360#
- Insulated, bulletproof (Kevlar sandwich)
- EMP protection

Portable Renewable Energy Solutions
Enabling Technological Advancements

Encapsulated polycrystalline PV

- Encapsulation eliminates aluminum frame
- Simplifies assembly process
- U.S. -made
- Highest efficiency possible with COTS product

Portable Renewable Energy Solutions
Enabling Technological Advancements

Lithium Iron Phosphate Energy Storage (LiFePO4)

- Much lighter than lead-acid, NiCad
- Safer than Lithium-polymer
- Faster charge, no heat issues
- Integrated battery charging / power management

Solar Power Adapters and Deployable and Renewable Alternative Energy Module

Major David C. Morris
Deputy Program Manager / Project Officer
david.c.morris@usmc.mil

AGENDA

- **SPACES Project**
  - **Past Solar Power Adapter Efforts (SPACES)**
  - **Current SPACES Projects**
    - **Multipurpose Solar Device**
    - **24 Volt Tactical Radio Power Adapter (RPA)**
    - **Computer Power Adapter**
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  - **Lead-acid battery chargers**
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    - **Vehicle**
  - **Communications-electronics battery charger**
  - **Computer power adapter and battery charger**
  - **Radio power adapter and battery chargers**
    - **12 Volt Tactical Radios**
    - **24 Volt Tactical Radios**
  - **Variable power supply**

SPACES v1.0 OUTCOME

ITEM	OUTCOME
Lead Acid (Gen)	GSA (Pulse-Tech)
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  SP-BC-LA-V (Vehicle)
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LEAD-ACID BATTERY CHARGERS

- **Current status:**
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  - **Available**
  - **Modification Instruction (MI) for generator version is complete and published for TQG series**
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SPACES v2.2 STRATEGY

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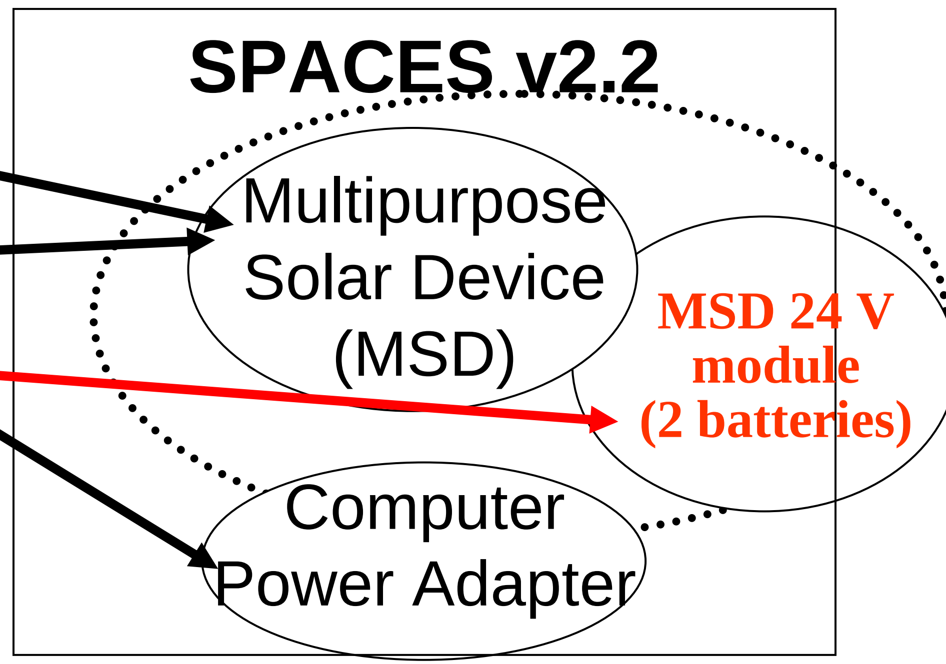
- The original strategy for SPACES was to pursue an integrated system for the second generation.
- Our approach is to seek an integrated solution now rather than continue to pursue the original SPACES items.
- Focus is on three items that provide full capability set of the original project:
  – Multipurpose Solar Device (MSD)
  – 24 Volt Radio Power Adapter
  – Computer Power Adapter

REVISED DEVELOPMENT PATH

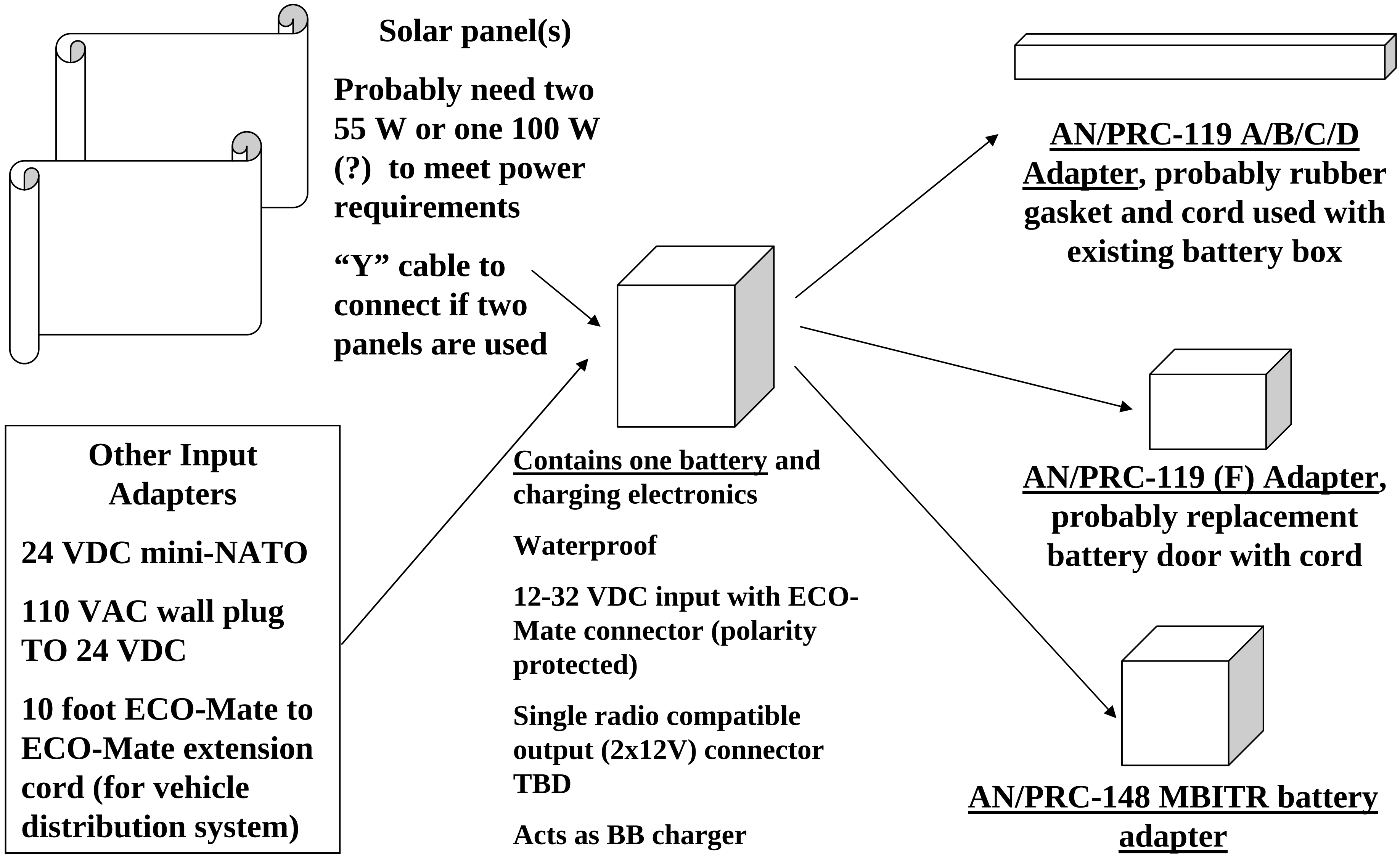
1. SP-BC-LA-G(enerator)
2. SP-BC-LA-V(ehicle)
3. SP-BC-BB
4. SP-CPA-BC
5. SP-RPA-BC-12V
6. SP-RPA-BC-24V
7. ~~SP-VPS~~



MSD SYSTEM CONCEPT

- Multipurpose Solar device (MSD)
- Multiple components packaged together as a kit.
- Components may be used or left behind as the mission dictates (within weight limit of 12 lbs).
- “Heart” of the system is a battery box/battery charger.
- Battery box/battery charger accepts multiple types of power input.
- Battery box/battery charger has an output connector that allows adapters to power various 12 Volt tactical radios.
- Expanded capability for 24 Volt radios is a planned upgrade.

MULTIPURPOSE SOLAR DEVICE



MSD VS SP4 AND SP4+

	SP4	SP4+	MSD
Solar Input	**Yes**	**Yes**	**Yes**
Other DC Input	**No**	**Yes**	**Yes**
AC Input	**No**	**Yes**	**Yes**
Charge BB-2590/U	**Yes**	**Yes**	**Yes**
Charge BB-390B/U	**No**	**?**	**Yes**
Charge other batteries	**No**	**Yes**	**No**
Radio Power Adapter	**No**	**No**	**Yes**

MSD TIMELINE

• Discussions with vendors	Feb 07-Apr 07
• Request For Proposals	May 07-Jul 07
• Select/Award up to two vendors	Oct 2007
• Deliver 2 systems for Test	Dec 2007
• First article Testing and LUE	Dec 07-Mar 08
• Select final configuration/vendor	Mar 08
• Conduct Production Verification Test and FUE	May 08-Aug 08
• Production Articles available	late 08/early 09

SPACES v2.0

- **Multipurpose Solar device (MSD)**

  In Progress

- **24 Volt Radio Power Adapter**

  Planned Upgrade to MSD

- **Computer Power Adapter**

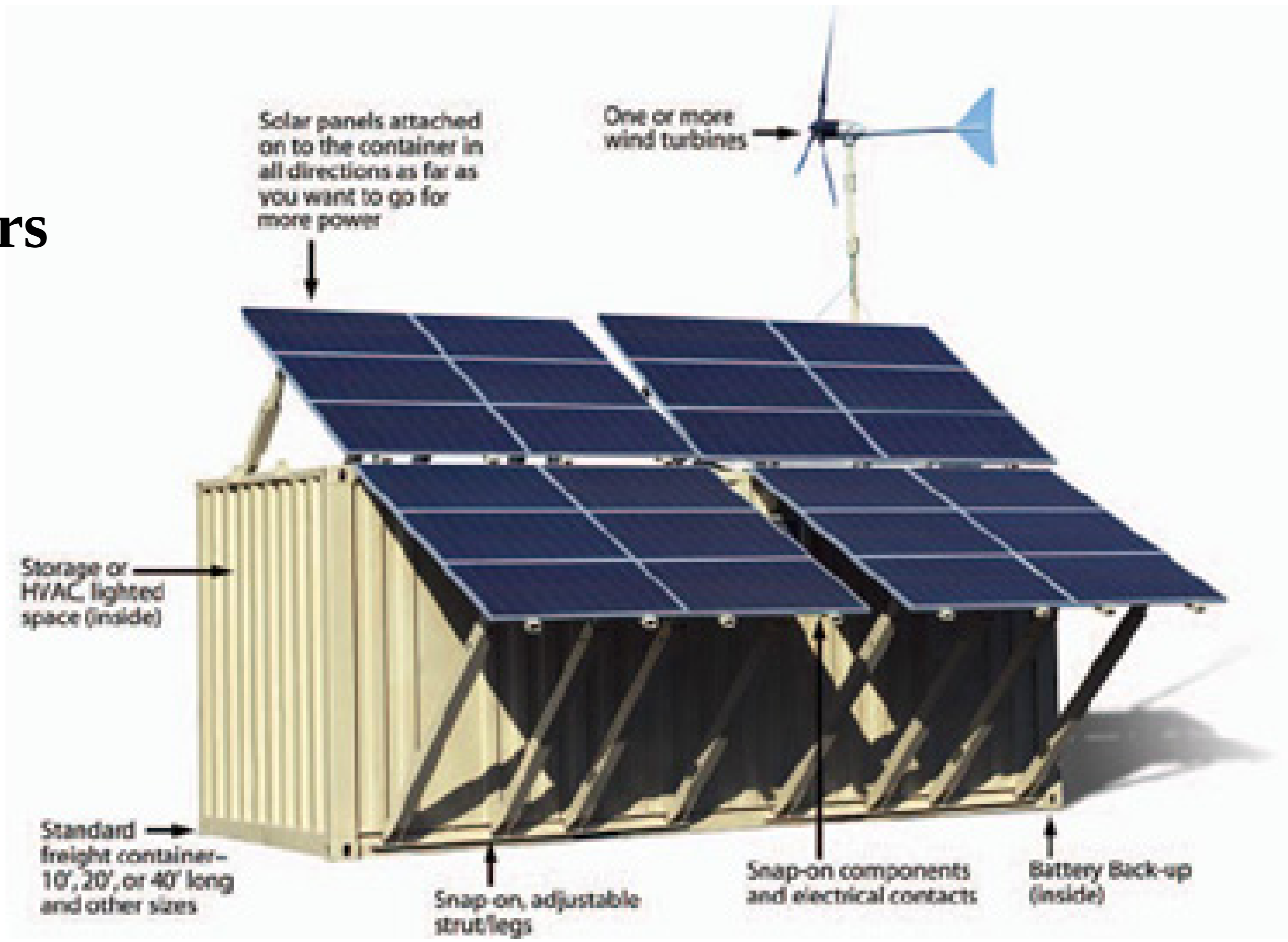
  Pending

SPACES MSD

- What are we doing differently this time?
  - Released a request for information to industry and disseminated as widely as possible.
  - Modified performance specification based on responses.
  - Open to discussions on draft performance specification prior to release of request for proposals.
  - Changed contracting strategy to include a separate phase for first article production (in place of bid samples)

DREAM PROJECT

- **Deployable & Renewable Energy Alternative Module (DREAM)**
- **Combination:**
  - **Diesel generators (backup)**
  - **Solar**
  - **Wind**
  - **Battery storage**



DREAM PROJECT

- **MNF-West (Iraq) submitted Joint Rapid Resource Request**
- **Objective is for 3 alternative/renewable energy capabilities to lessen fuel transport demand**
  - **<u>HMMWV Towable small system – 3-5 kilowatts output power</u>**
  - **Medium Truck Towable – 10-15 kilowatts output power**
  - **Heavy Truck Transportable – 30 kilowatts output power**
- **We have selected the small (3-5 kW) system as the first effort.**

DREAM PROJECT

- **USMC effort with ONR Rapid Technology Transition (RTT) funding (FY07-08)**
  - **Loaded Weight $\leq$ 4200 lbs**
  - **HMMWV towable**
  - **Up to 5 kW Output (3 kW continuous output)**
  - **Energy storage in batteries**
  - **May use:**
    - **solar**
    - **wind**
    - **Back-up generator**
  - **$\geq$ 15 days without refuel**

Previous US Army demonstration

DREAM PROJECT

- **Contract is for R&D - 3 phases**
  - **Phase 1 – Trade-studies for system performance, sizing**
  - **Phase 2 (Option 1) - Build, test, and demonstrate prototype system**
  - **Phase 3 (Option 2) - Support to Government test events**
- **Schedule:**

Award	**Apr 07 (three vendors)**
Phase 1	**Apr 07-Jul 07 (three vendors)**
Phase 2	**Jul 07-Feb 08 (up to two vendors)**
Phase 3	**Mar 08-Jul 08 (one vendor)**

  - **Final hardware configuration available late 08/early 09**

DREAM PROJECT

Questions ?

Major David C. Morris
david.c.morris@usmc.mil
(703) 432-3607
http://www.marcorsyscom.usmc.mil/sites/pmeps/default.asp

Self-Generated Field Power Sources

2007 Joint Service Power Expo

Albert Hartman

High Tide Associates

Mobile Electronics

- Power Requirements
- Available Field Sources
- EM Energy-Harvesting Technology

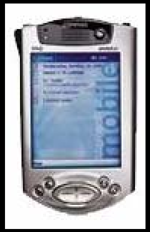
Electrical Power Req's

1. How Many Watts?
2. Usage Duty Cycle? (intermittent/continuous?)












0 1 5 10 30 100

Watts

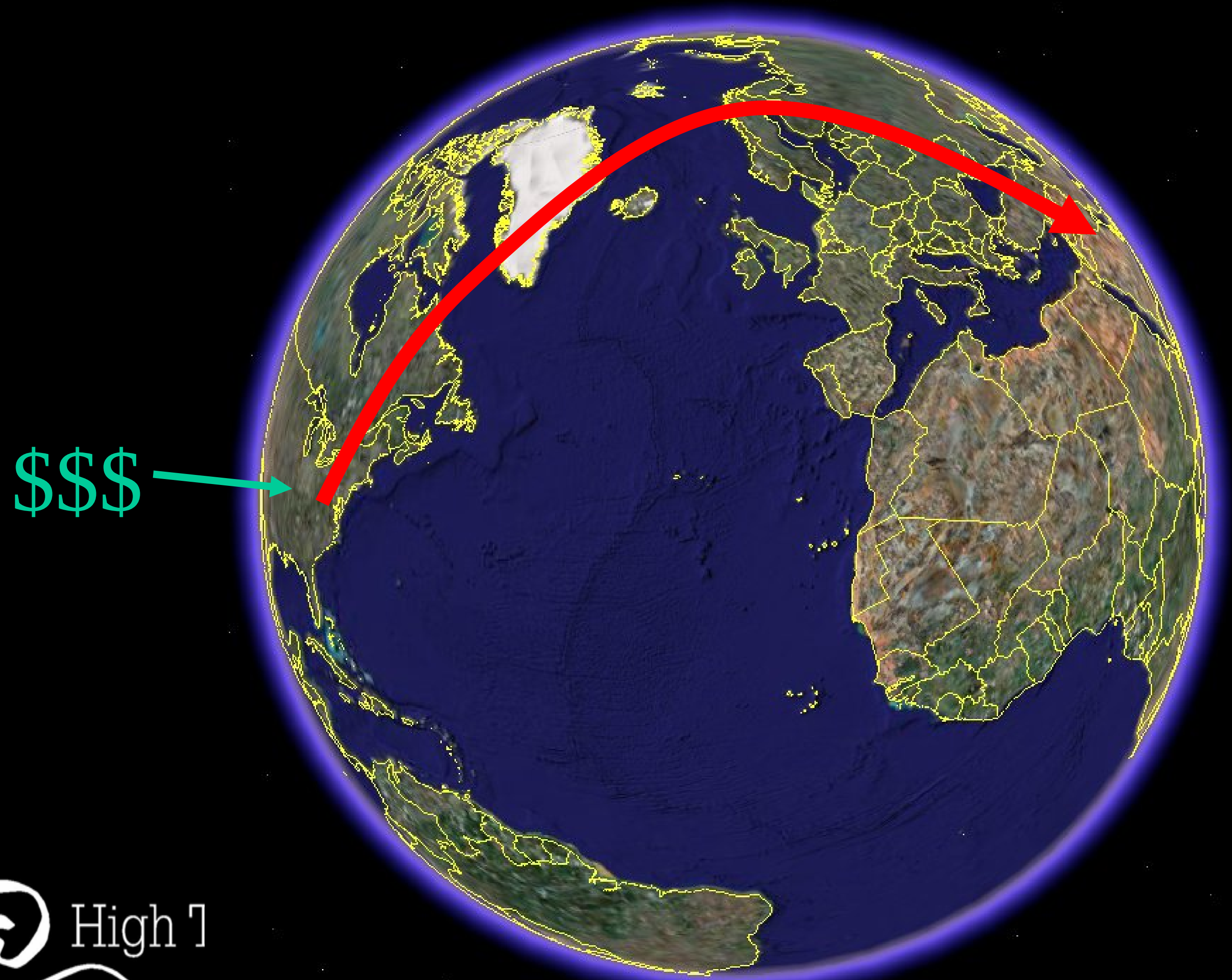
High Tide Associates

Chemical Batteries

- Enabled mobile electronics
- Industry - 6%/yr, cheap labor/lax laws
- Primaries - use once, dispose. $60B
- Secondaries - $6B

Primary Batteries Procurement

Difficult & Expensive



Primary Batteries Disposal

Spending Money & Taking Risks

for ***Trash!***

High Tide Associates

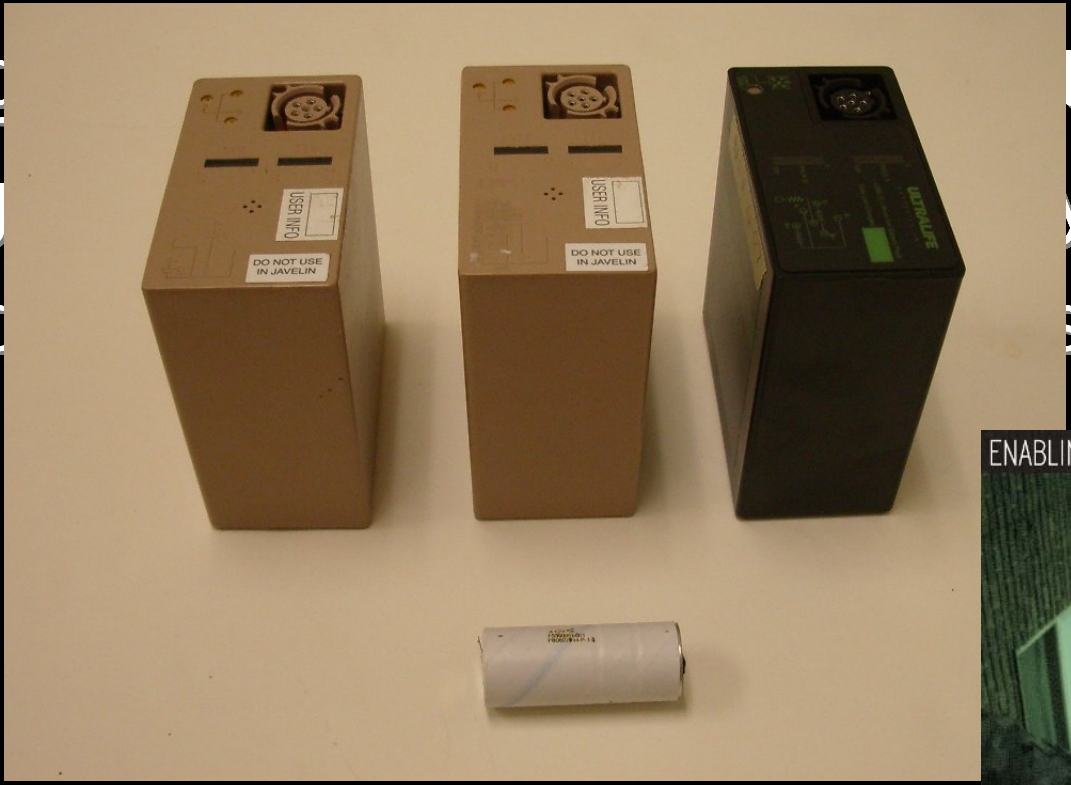
Secondaries

- Economics driving popularity
  - cellphones, computers, ipods, shavers, toothbrush
  - electric car
- Nothing new, Li-ion 6%/yr
- MIL directive to use rechargeables
  - replace only 1/yr

High Tide Associates

Secondaries - Power

- Hug… tts
- Log… y chain
- Red… smaller



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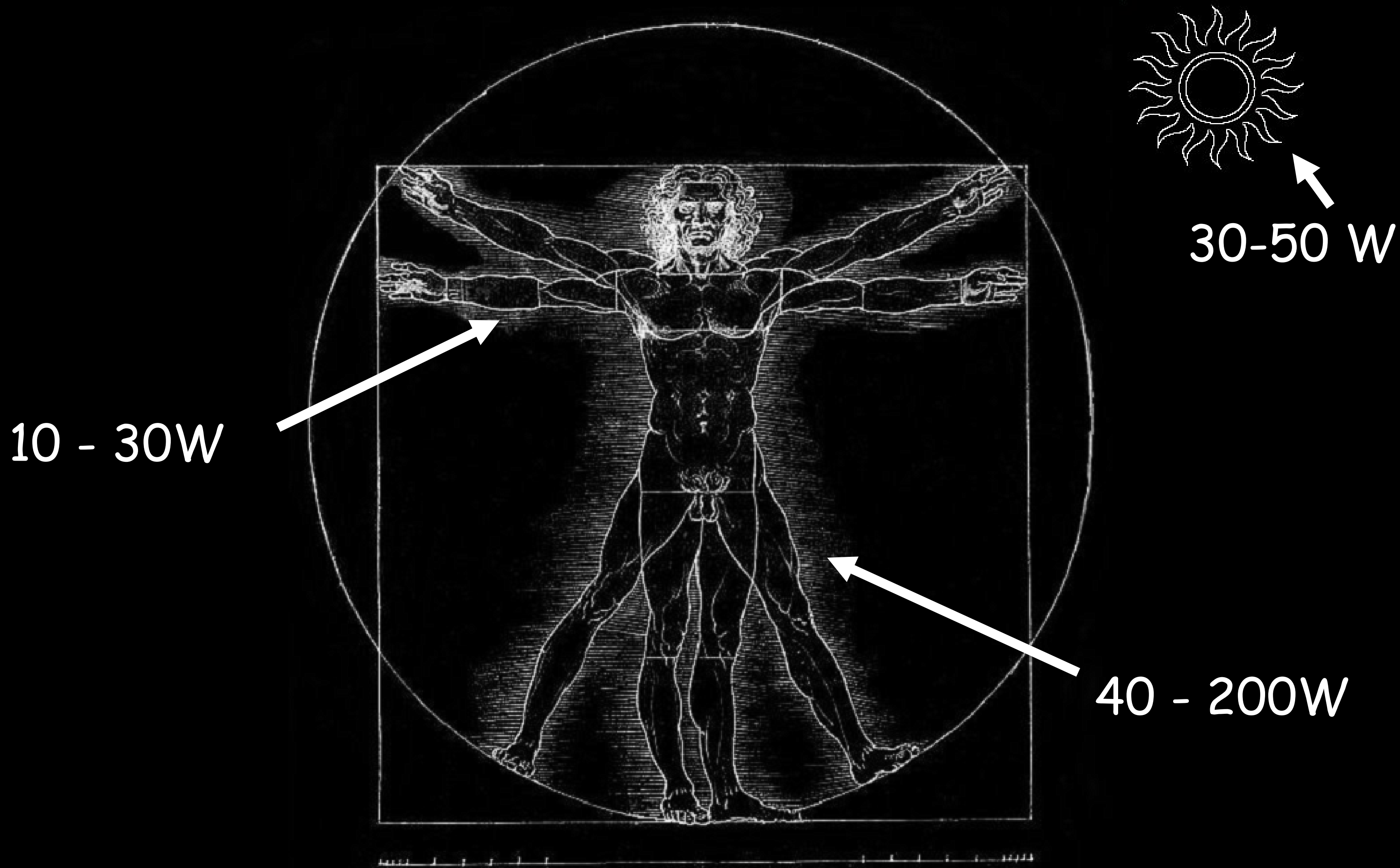
How Much Should You Pack?

Energy is Everywhere

- Can Find a Fresh AA every 5-10 mins

High Tide Associates



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If You Can Walk Up These Stairs …

So How Much Effort Does it Take?

You Can Charge a AA Battery

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How About Us?

- Leverage Hard Disk Drive technology (electro-magnetics, digital switchers, uP)
- All electricity comes from E-M
- Human power is same as as diesel or hydro or nuke or wind, etc.

Early Effort

- Made a modern G-67

Stuff We Found Out

- Power Variability: users, time
- Destructive Power Levels, need buffer
- User Interface: ergonomics (50%), info, effort adjust
- Multiple devic
  sinks

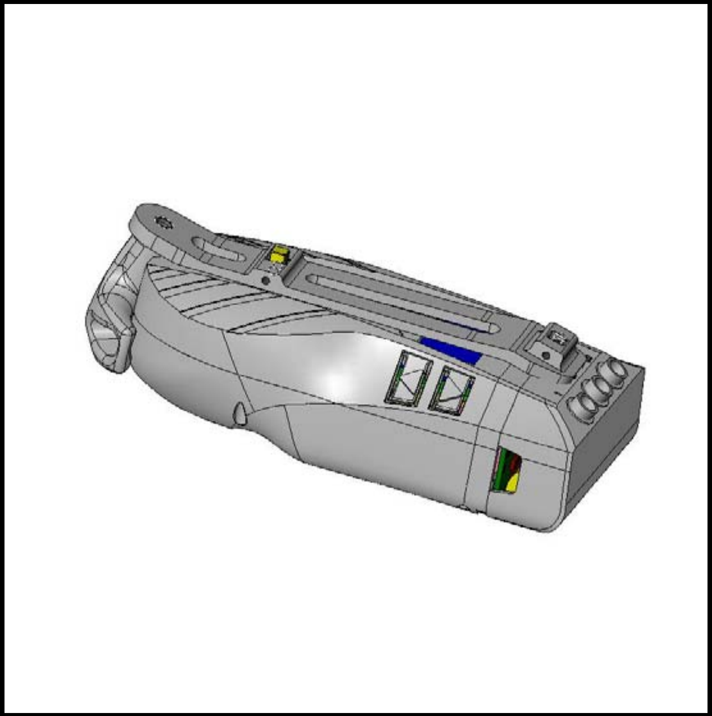
High Tide Associates

Stuff We Found Out (cont.)

- Unanticipated Uses: PV, UPS, volt conversion (AUX)

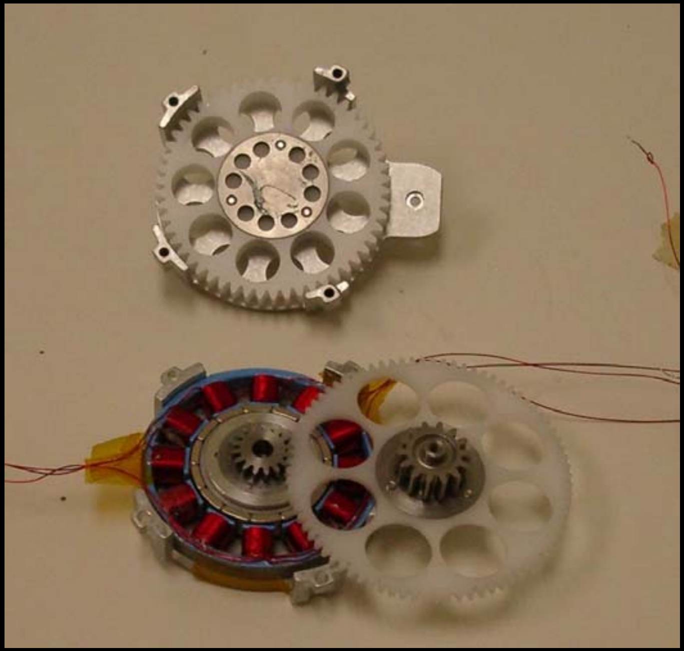
- Connectors: many MIL, use COTS, cig lighter, USB

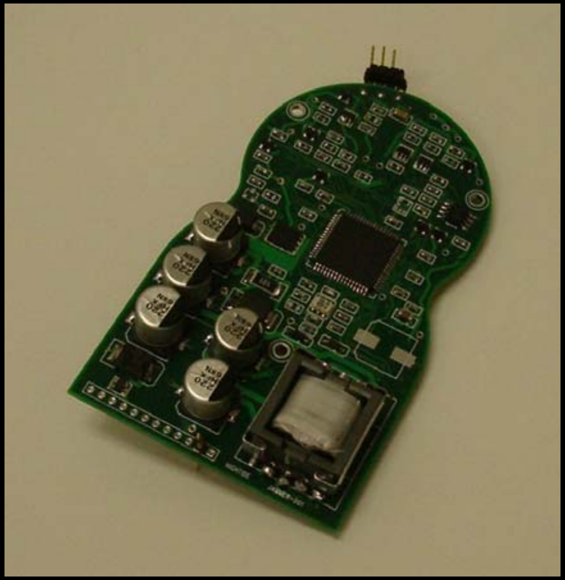
Current System Overview



High Tide Associates

Jammer P125





High Tide Associates

Applications

- Emergency kits - crash kits, rubber rafts air/seacraft, w/first aid kits
- Dismounted soldier rucksacks
- Anything low power (single AA apps)
- Looking For Your Ideas Too

We`re Putting A Build Together

- 5 yr history: CECOM Powerbranch, SOCOM
- Add Your Name to the List
- Controls Charger Costs
- Last chance for input before hardtool lockdown

High Tide Associates

Recap:

- Mobile Electronics - great, modest power
- Plenty of power everywhere
- Portable EM chargers are effective
- Dead batteries? No problem.

Field Energy Harvesting with High Tide

You Are <u>NEVER</u> Without Power

High Tide Associates

Contact Info:

Albert Hartman
650-245-5424
ahartman@hightidelabs.com

Solar Power Adapters
and
Deployable and Renewable Alternative Energy Module

Major David C. Morris
Deputy Program Manager / Project Officer
david.c.morris@usmc.mil

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  - **Past Solar Power Adapter Efforts (SPACES)**
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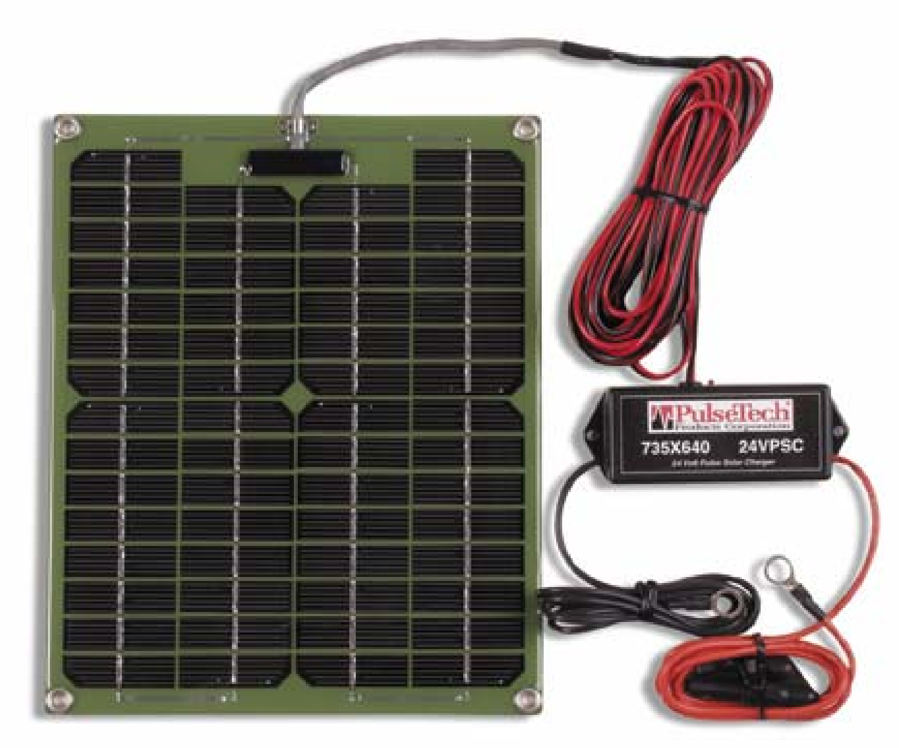

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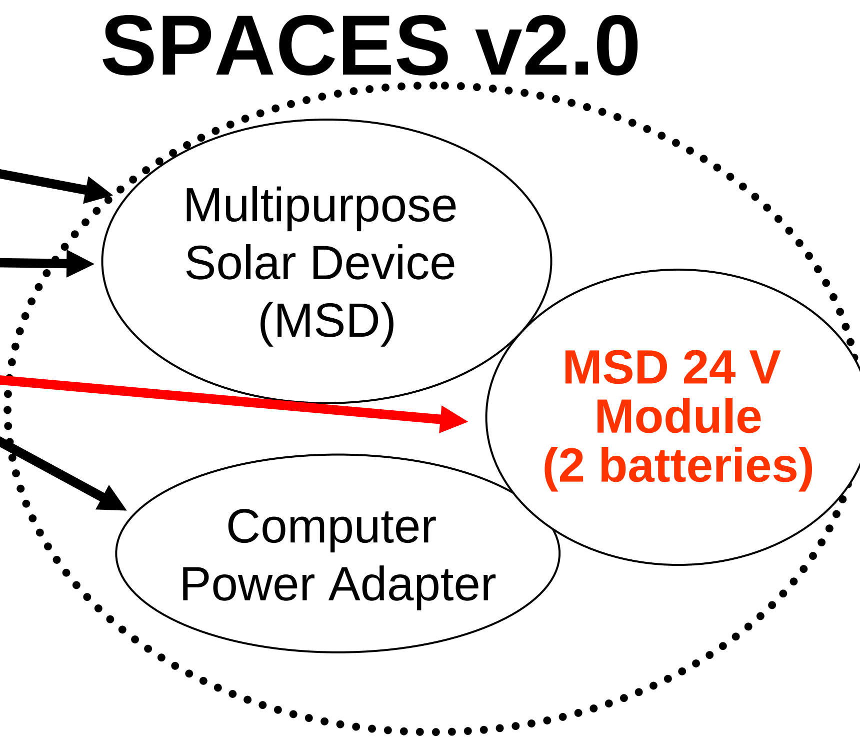
REVISED DEVELOPMENT PATH

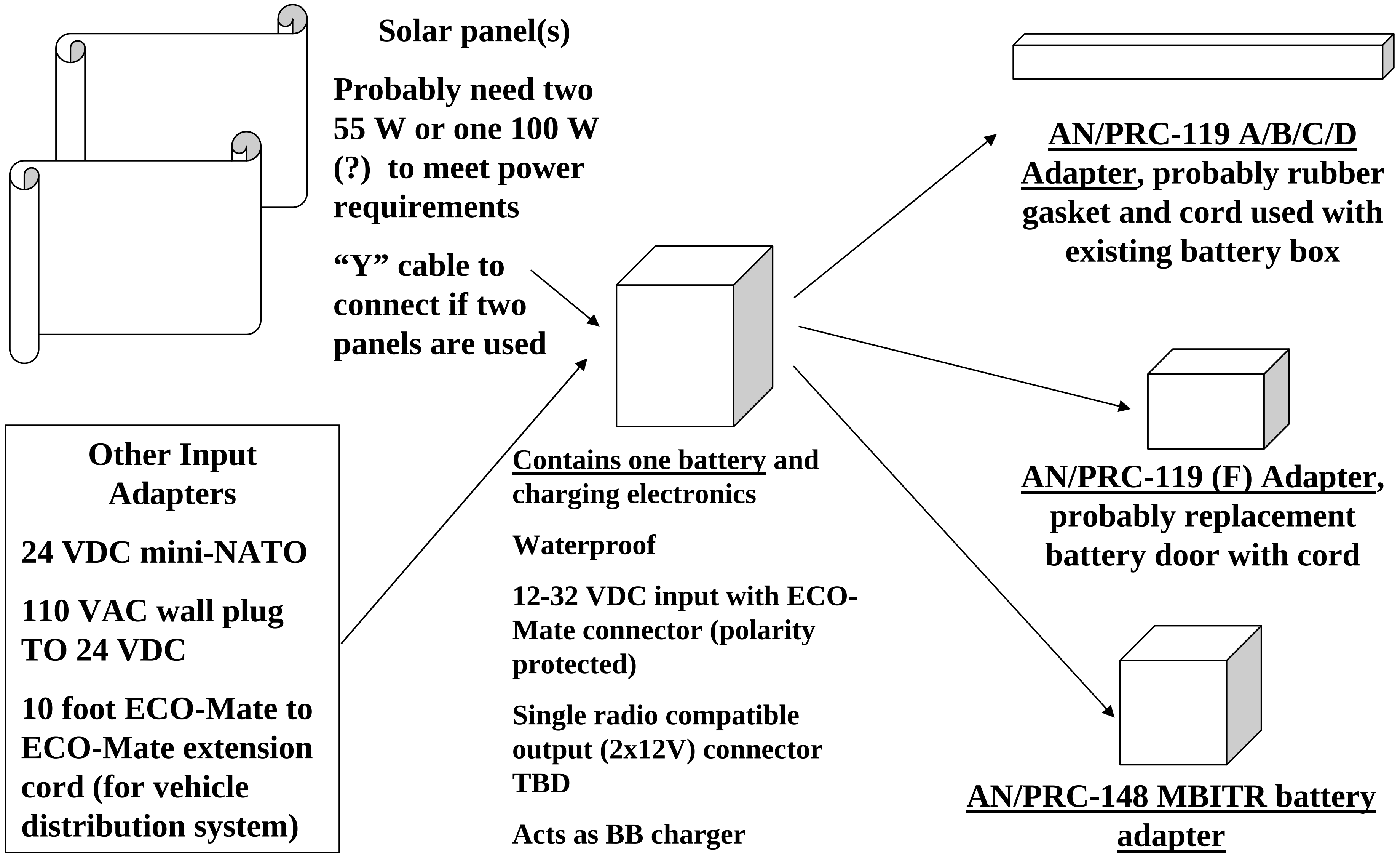
1. SP-BC-LA-G(enerator)
2. SP-BC-LA-V(ehicle)
3. SP-BC-BB
4. SP-CPA-BC
5. SP-RPA-BC-12V
6. SP-RPA-BC-24V
7. ~~SP-VPS~~



MSD SYSTEM CONCEPT

- **Multipurpose Solar device (MSD)**
- **Multiple components packaged together as a kit.**
- **Components may be used or left behind as the mission dictates (within weight limit of 12 lbs).**
- **“Heart” of the system is a battery box/battery charger.**
- **Battery box/battery charger accepts multiple types of power input.**
- **Battery box/battery charger has an output connector that allows adapters to power various 12 Volt tactical radios.**
- **Expanded capability for 24 Volt radios is a planned upgrade.**

MULTIPURPOSE SOLAR DEVICE



MSD vs SP4 & SP4+

	SP4	SP4+	MSD
Solar Input	**Yes**	**Yes**	**Yes**
Other DC Input	**No**	**Yes**	**Yes**
AC Input	**No**	**Yes**	**Yes**
Charge BB-2590/U	**Yes**	**Yes**	**Yes**
Charge BB-390B/U	**No**	**?**	**Yes**
Charge other batteries	**No**	**Yes**	**No**
Radio Power Adapter	**No**	**No**	**Yes**

MSD TIMELINE

Discussions with vendors	**Feb 07-Apr 07**
Request For Proposals	**May 07-Jul 07**
Select/Award up to two vendors	**Oct 2007**
Deliver 2 systems for Test	**Dec 2007**
First article Testing and LUE	**Dec 07-Mar 08**
Select final configuration/vendor	**Mar 08**
Conduct Production Verification Test and FUE	**May 08-Aug 08**
Production Articles available	**late 08/early 09**

SPACES v2.0

- **Multipurpose Solar device (MSD)**

  In Progress

- **24 Volt Radio Power Adapter**

  Planned Upgrade to MSD

- **Computer Power Adapter**

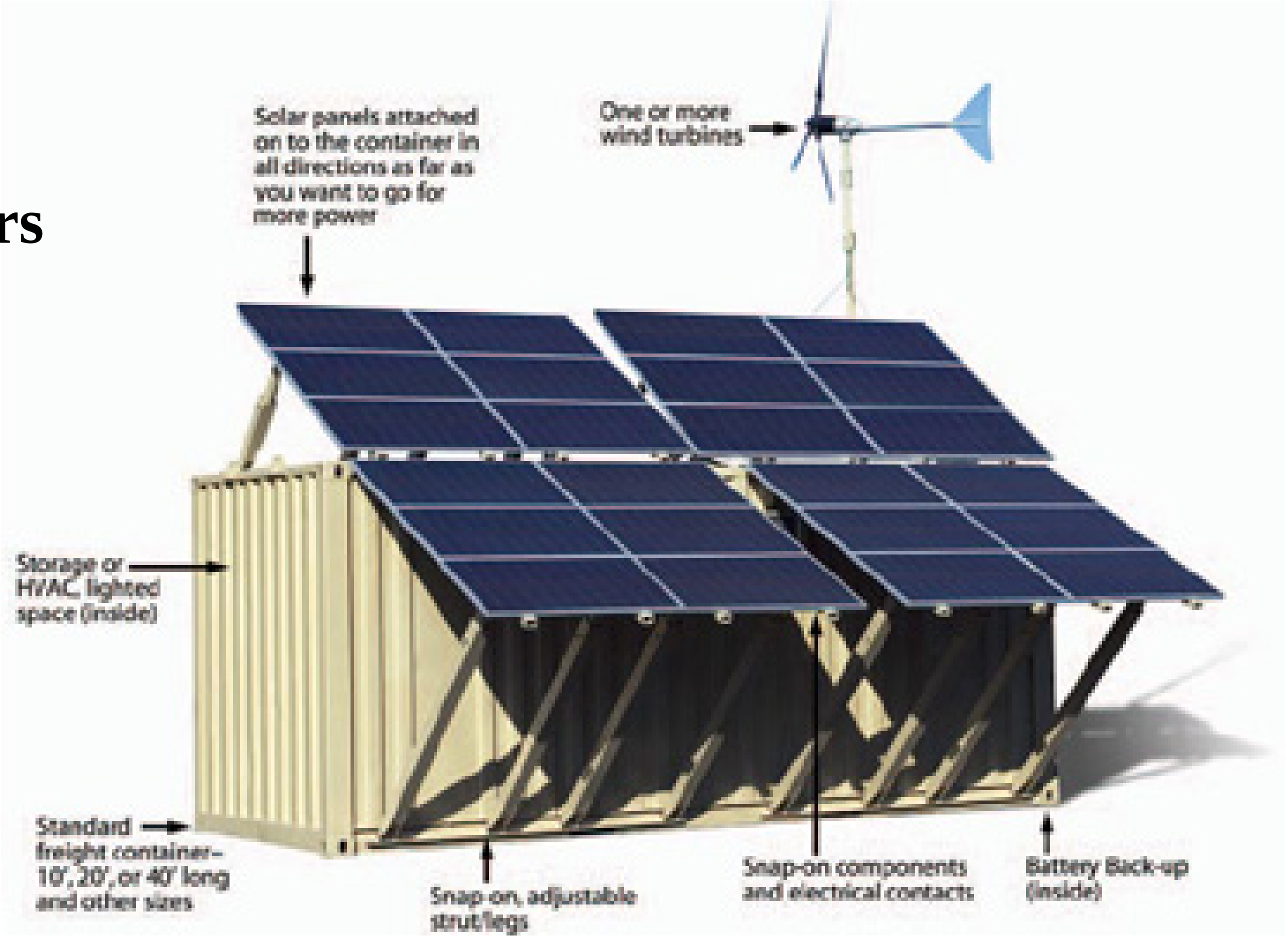
  Pending

SPACES MSD

- **What are we doing differently this time?**
  - **Released a request for information to industry and disseminated as widely as possible.**
  - **Modified performance specification based on responses.**
  - **Open to discussions on draft performance specification prior to release of request for proposals.**
  - **Changed contracting strategy to include a separate phase for first article production (in place of bid samples)**

DREAM PROJECT

- **Deployable & Renewable Energy Alternative Module (DREAM)**
- **Combination:**
  - **Diesel generators (backup)**
  - **Solar**
  - **Wind**
  - **Battery storage**



DREAM PROJECT

- **MNF-West (Iraq) submitted Joint Rapid Resource Request**
- **Objective is for 3 alternative/renewable energy capabilities to lessen fuel transport demand**
    - **<u>HMMWV Towable small system – 3-5 kilowatts output power</u>**
    - **Medium Truck Towable – 10-15 kilowatts output power**
    - **Heavy Truck Transportable – 30 kilowatts output power**
- **We have selected the small (3-5 kW) system as the first effort.**

DREAM PROJECT

- **USMC effort with ONR Rapid Technology Transition (RTT) funding (FY07-08)**
  - **Loaded Weight $\leq$ 4200 lbs**
  - **HMMWV towable**
  - **Up to 5 kW Output (3 kW continuous output)**
  - **Energy storage in batteries**
  - **May use:**
    - **solar**
    - **wind**
    - **Back-up generator**
  - **$\geq$ 15 days without refuel**

Previous US Army demonstration

DREAM PROJECT

- **Contract is for R&D - 3 phases**
  - **Phase 1 – Trade-studies for system performance, sizing**
  - **Phase 2 (Option 1) - Build, test, and demonstrate prototype system**
  - **Phase 3 (Option 2) - Support to Government test events**
- **Schedule:**
  - **Award** **Apr 07 (three vendors)**
  - **Phase 1** **Apr 07-Jul 07 (three vendors)**
  - **Phase 2** **Jul 07-Feb 08 (up to two vendors)**
  - **Phase 3** **Mar 08-Jul 08 (one vendor)**
  - **Final hardware configuration available late 08/early 09**

DREAM PROJECT

Questions ?

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Large-sized Li-ion Battery Module for Hybrid Powered Energy System

Takefumi Inoue, Koichi Nishiyama*
and William A. Moll**

*** GS Yuasa Corporation**
****United Lithium Systems**

Background of Development

- Increasing demand of large-scale lithium ion batteries for high power industrial applications such as hybrid powered energy systems

Development of new, large-scale lithium ion cell and battery modules which have high power, long life and superior cooling performance

Agenda

- Cell Specifications, Technologies and Performance
- Battery Module Specifications and Cooling Evaluation
- Evaluation of Energy Efficiency for Hybrid Powered Energy System (Railway Vehicle Systems)

LIM30H Cell Specification

Mass / kg	2.0
Dimension / mm / in	47W, 170L, 133H 1.85” x 6.7” x 5.2”
Nominal voltage / V	3.6
Nominal capacity / Ah	30

Key Technologies of LIM30H

- **Positive active material:**

  $LiMn_2 0_4$ improved for safety and long life

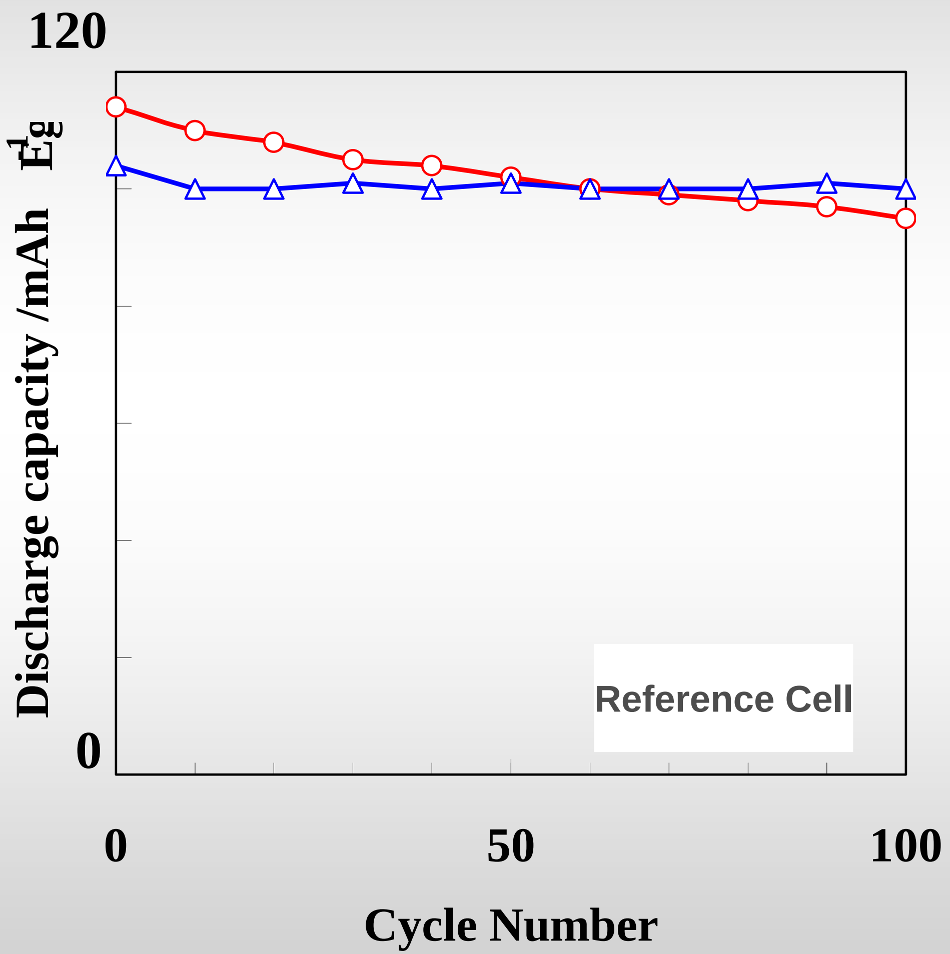
- **Negative active material:**

  Hard carbon for improved high rate charge/discharge performance and high energy efficiency

- **Structure:**

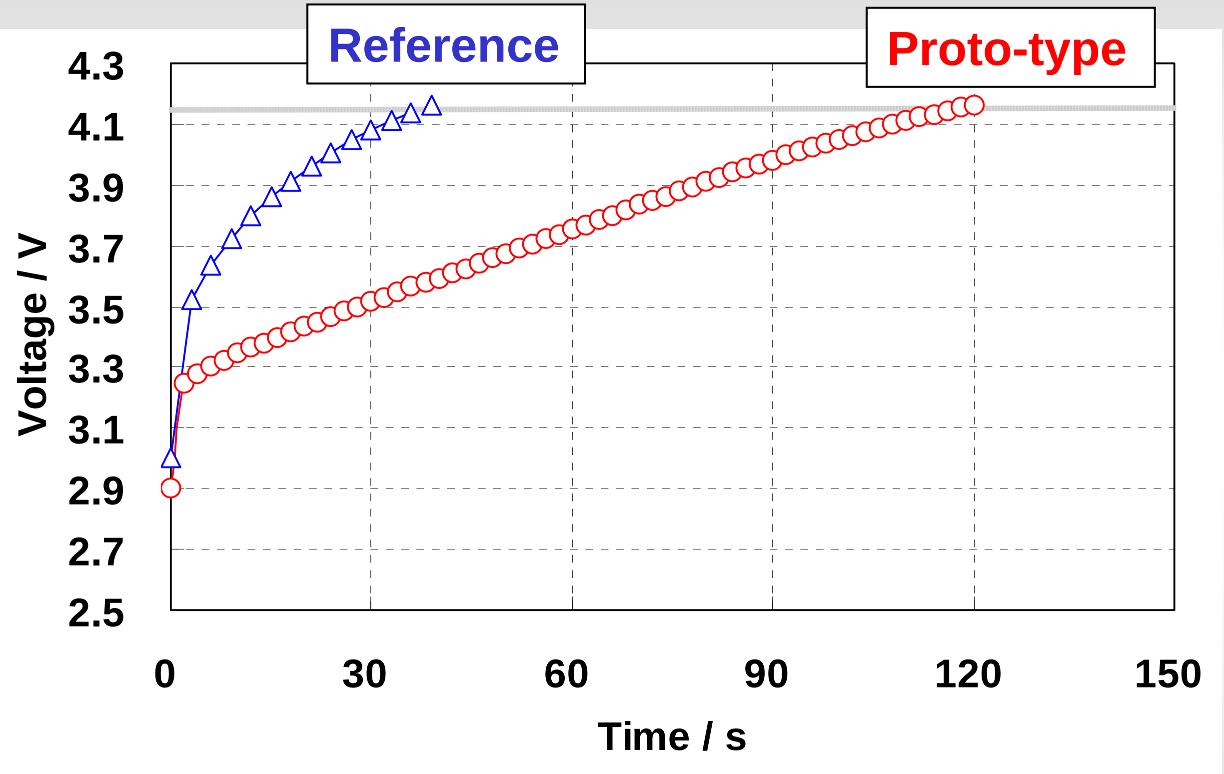
  Robust current collecting construction for high amperage charge/discharge

Cycle Life Performance of Improved Manganese Active Material



Charge : 1.0 mA / cm^2 to 4.3 V
Discharge : 2.0 mA / cm^2 to 3.0 V
Temperature : 60□ ž
Electrolyte : Standard
Working electrode : LiMn2O4
Counter electrode :Li metal
Reference electrode :Li metal

Quick Charge Performance of the Cells with Various Negative Active Materials



1. Proto-type cell — Negative active material: **Hard carbon**

2. Reference cell — Negative active material: **Graphite**

Charge conditions — Discharge : 1CA to 2.75 V at 25^{o}C

Charge : 10CA to 4.15 V at 25^{o}C

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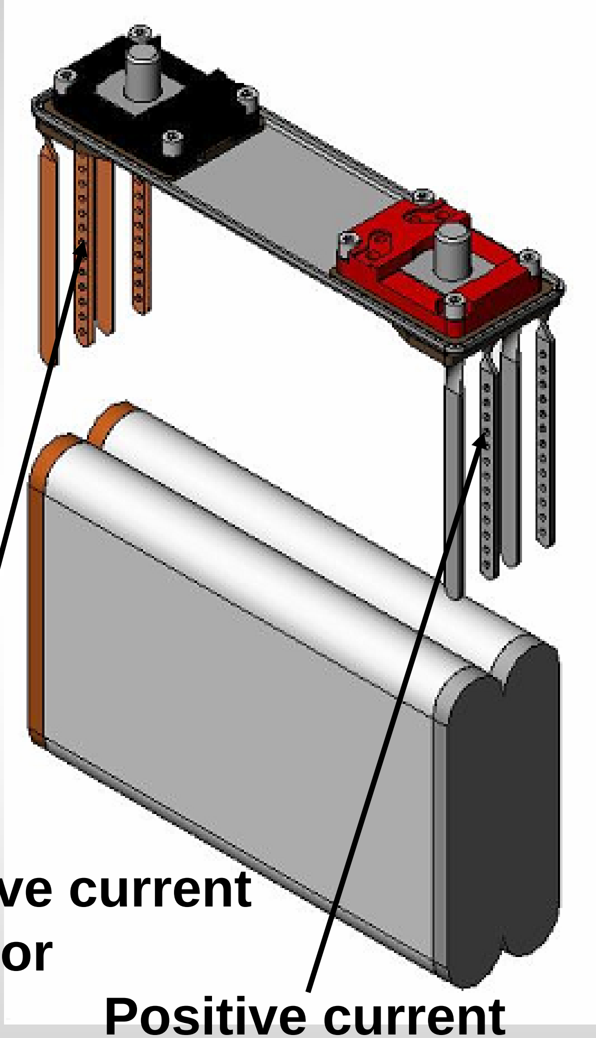
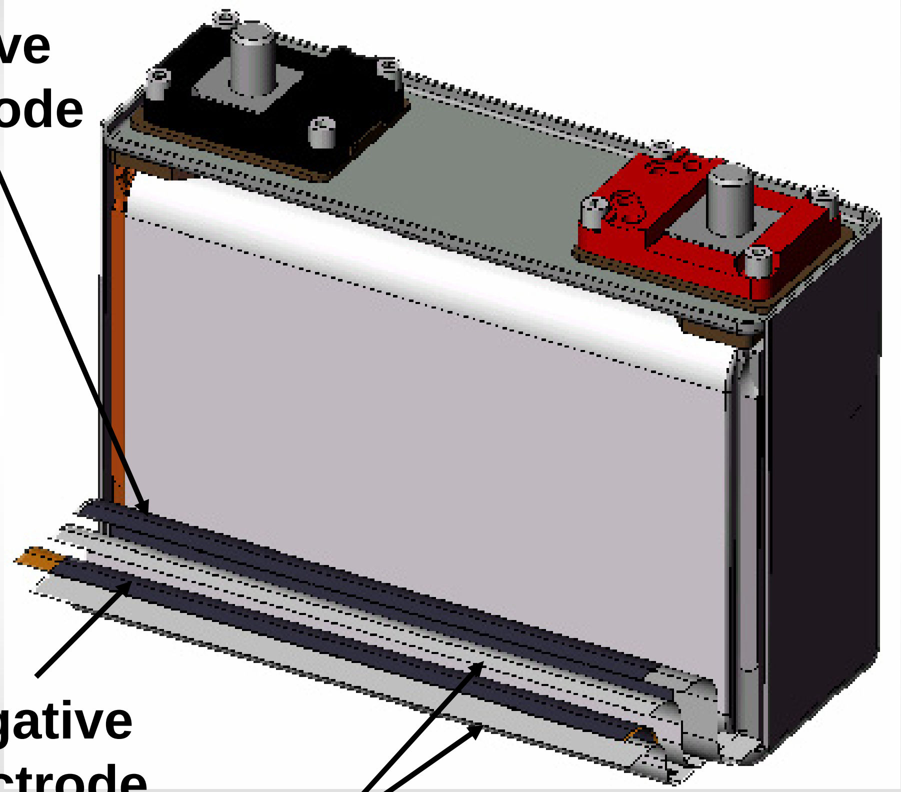
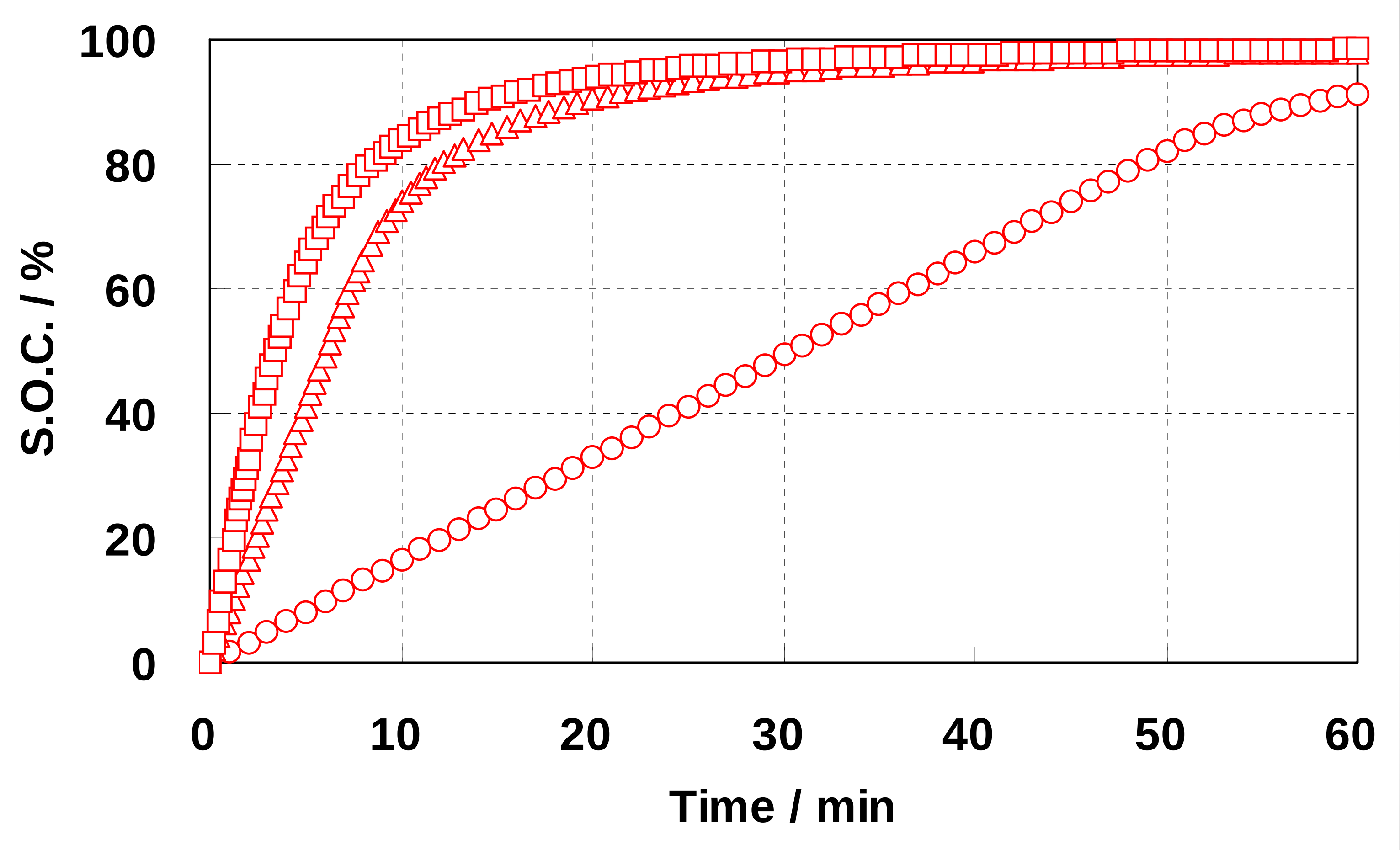
Structure of LIM30H



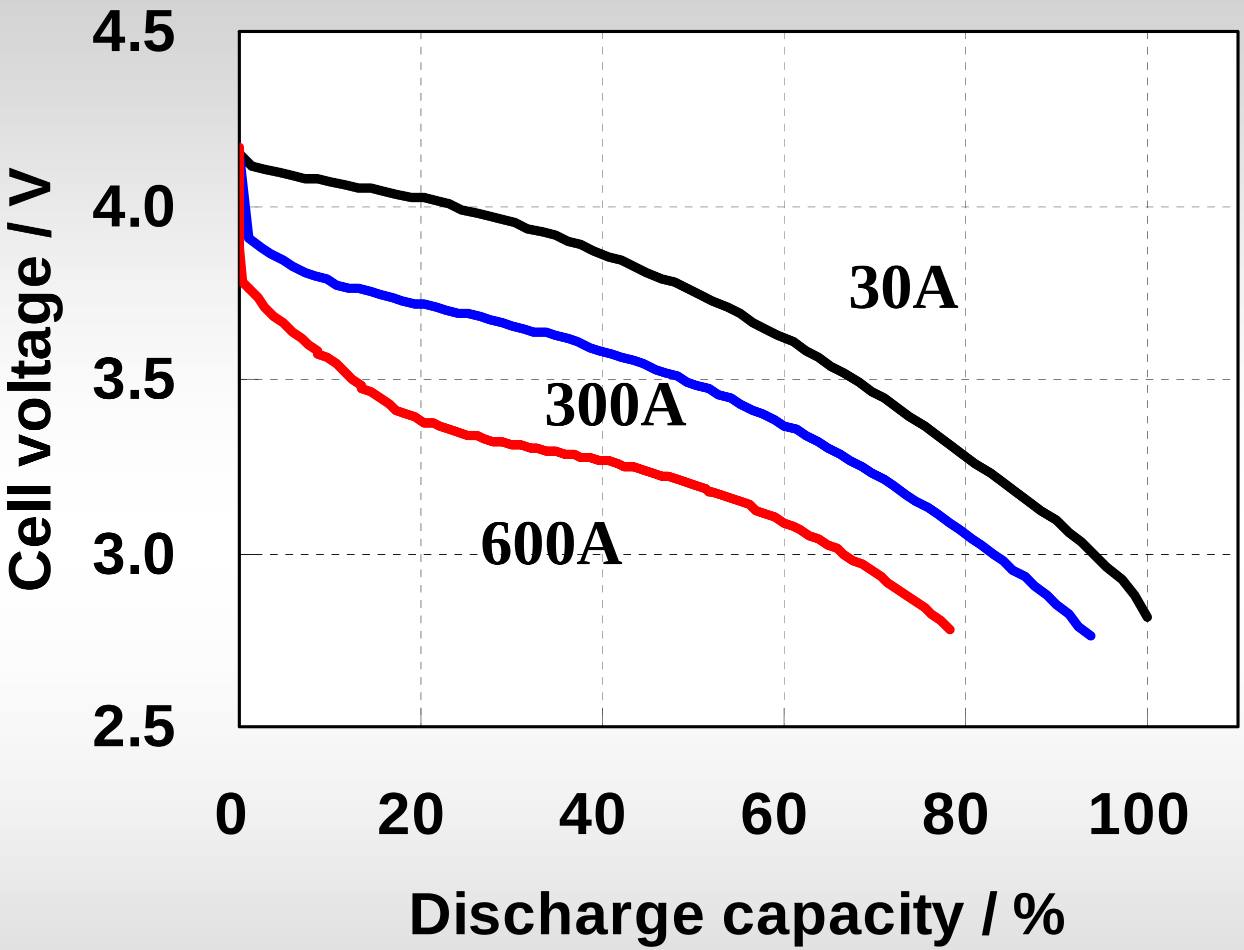


Quick Charge Performance of LIM30H



Charge : (○)30 , (□)150, and (□)300 A to 4.15 V followed by constant voltage of its value for 3 hours at 25 ^{o}C

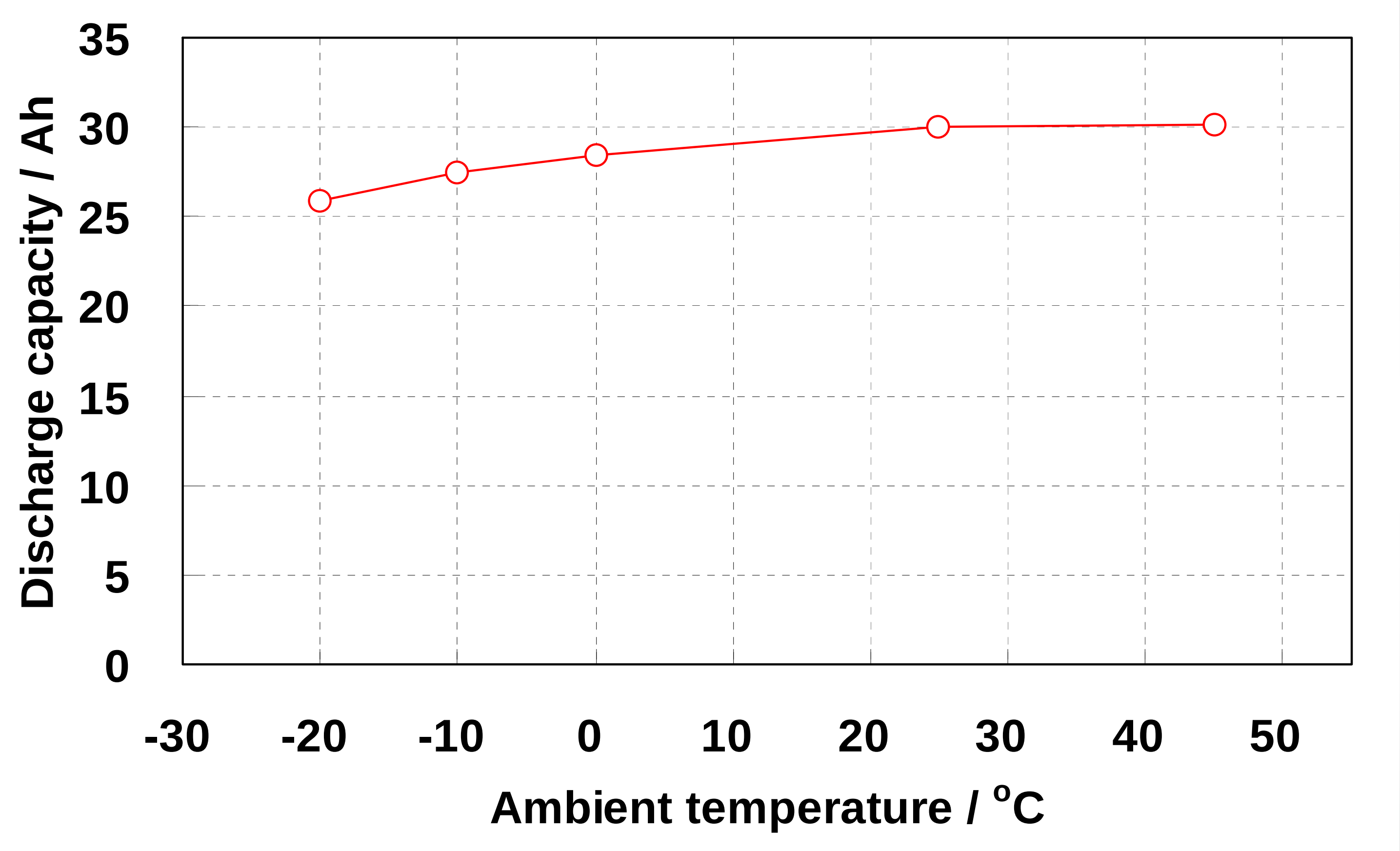
Discharge Performance of LIM30H



Charge : 30 A to 4.15 V followed by constant voltage of its value for 3 hours at 25^{o}C

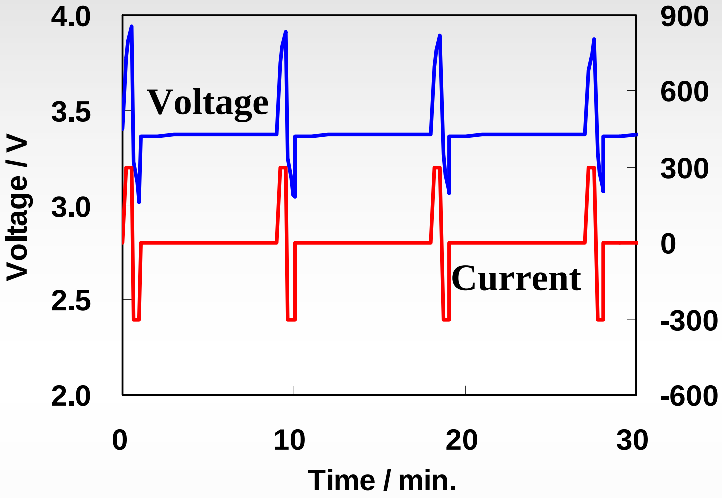
Discharge : Discharge with various current at 25^{o}C

Discharge Capacities of LIM30H at Various Ambient Temperature



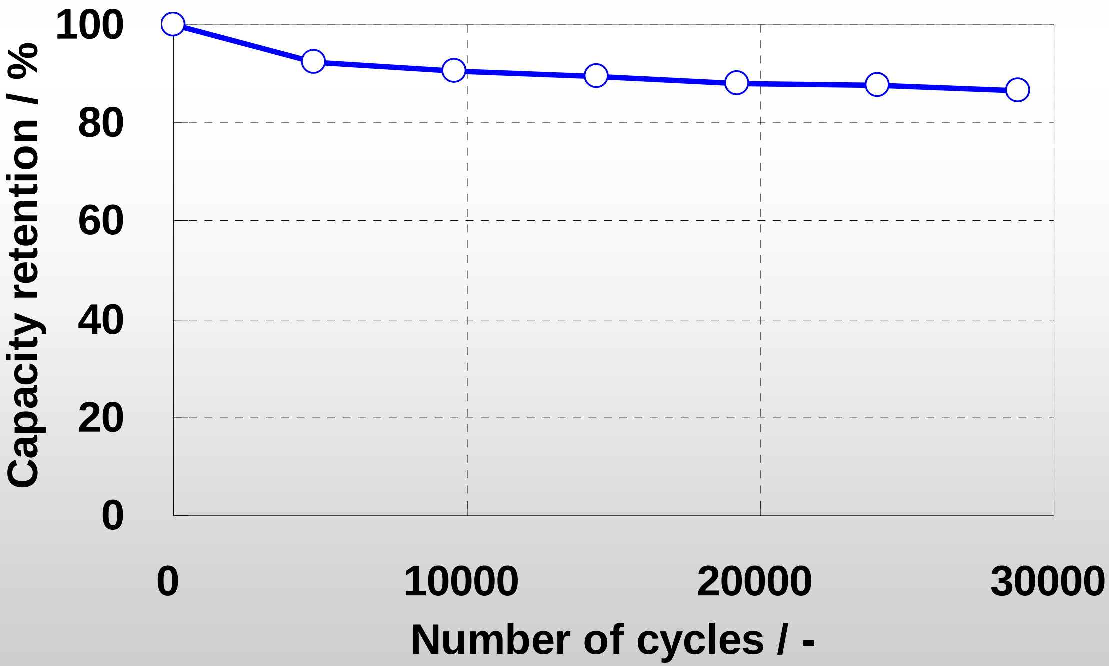
Charge : 30 A to 4.15 V followed by constant voltage for 3 hours at 25°C
Discharge : 30 A to 2.75 V at various ambient temperature

Life Performance of LIM30H under Large Current Charge Discharge Pulse Cycle



300A pattern cycle:

Charge- 300A 30sec.
Discharge- 300A 30sec.
Rest- 480sec.



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Agenda

- Cell Specifications, Technologies and Performance
- Battery Module Specifications and Cooling Evaluation
- Evaluation of Energy Efficiency for Hybrid Powered Energy System (Railway Vehicle Systems)

LIM30H-8R Module Specifications

Items	Specifications
Cell	LIM30H (8 cells in series)
Nominal capacity	30 Ah
Nominal voltage	28.8 V (3.6 V / cell)
Operating voltage	20.0 – 33.6 V (2.5 – 4.2 V / cell)
Dimensions	W231 – D375 – H147 / mm
Mass	18.5 kg
Cooling	Designed for forced air cooling
Cell management	Cell Scanner(CS) installed

LIM30H-8R

Negative Terminal

Positive Terminal

Air Intake

Cell Scanner

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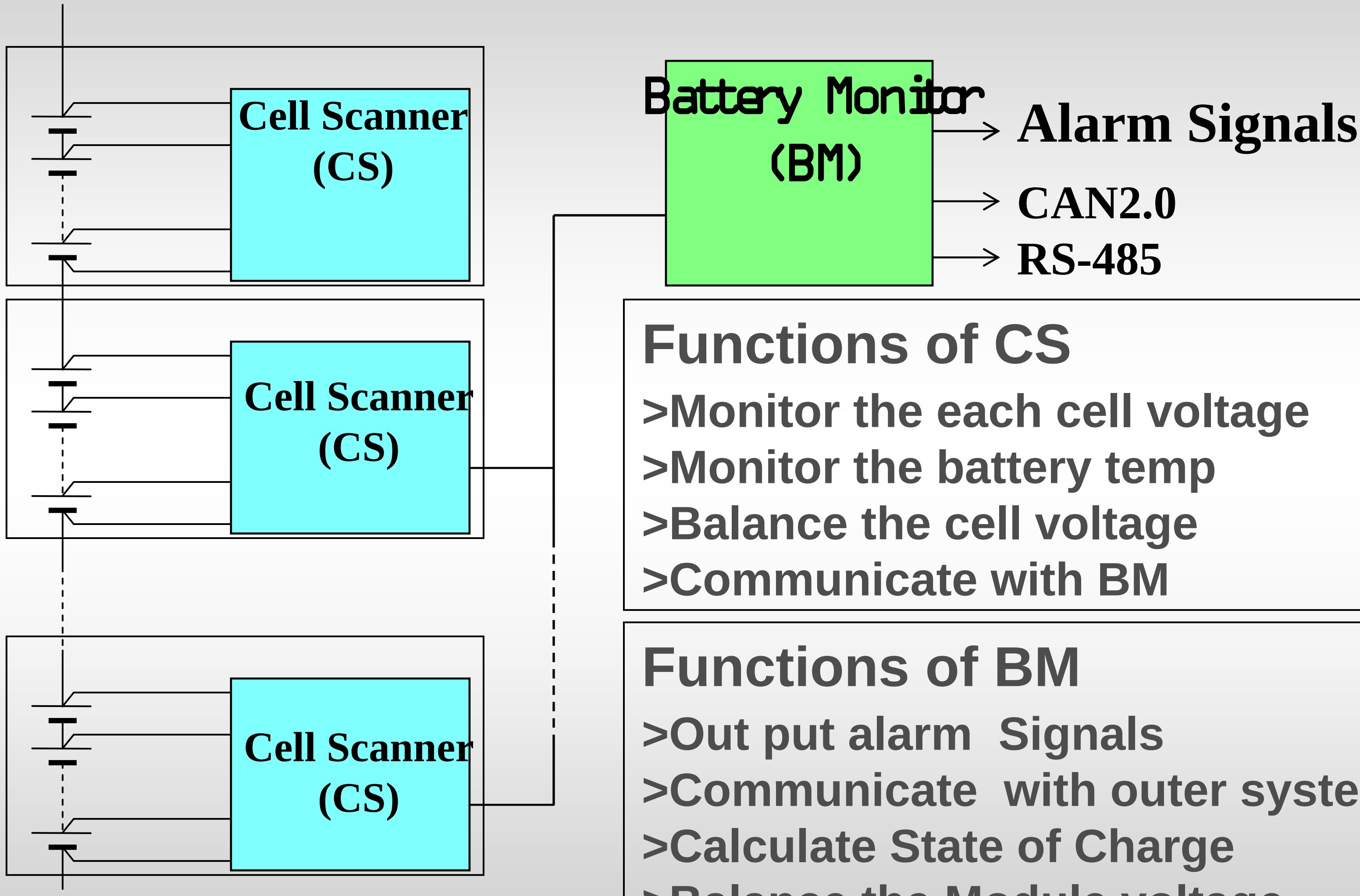
Battery Monitoring System of LIM30H-8R



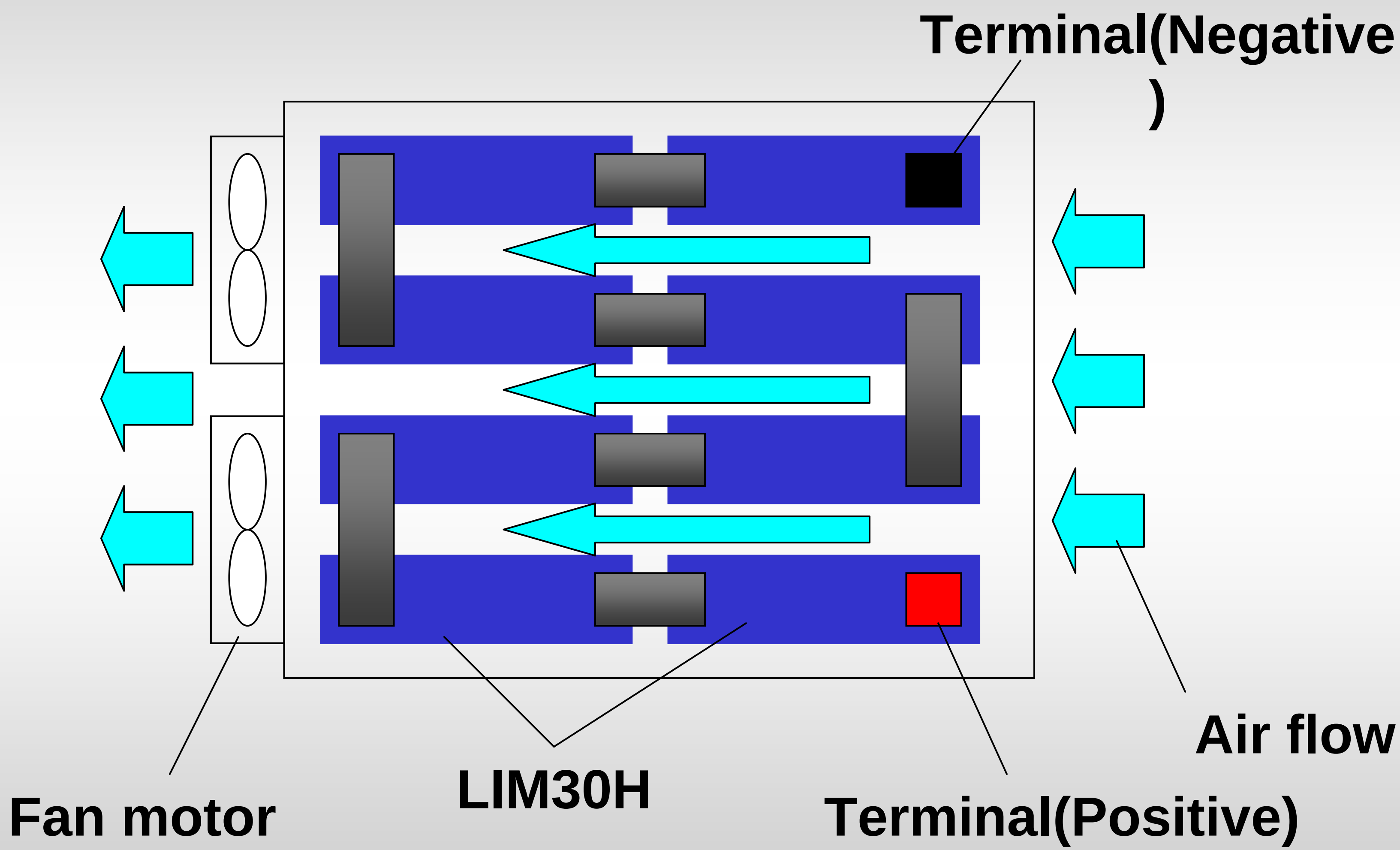
Functions of CS

>Monitor the each cell voltage
>Monitor the battery temp
>Balance the cell voltage
>Communicate with BM

Functions of BM

>Out put alarm Signals
>Communicate with outer systems
>Calculate State of Charge
>Balance the Module voltage

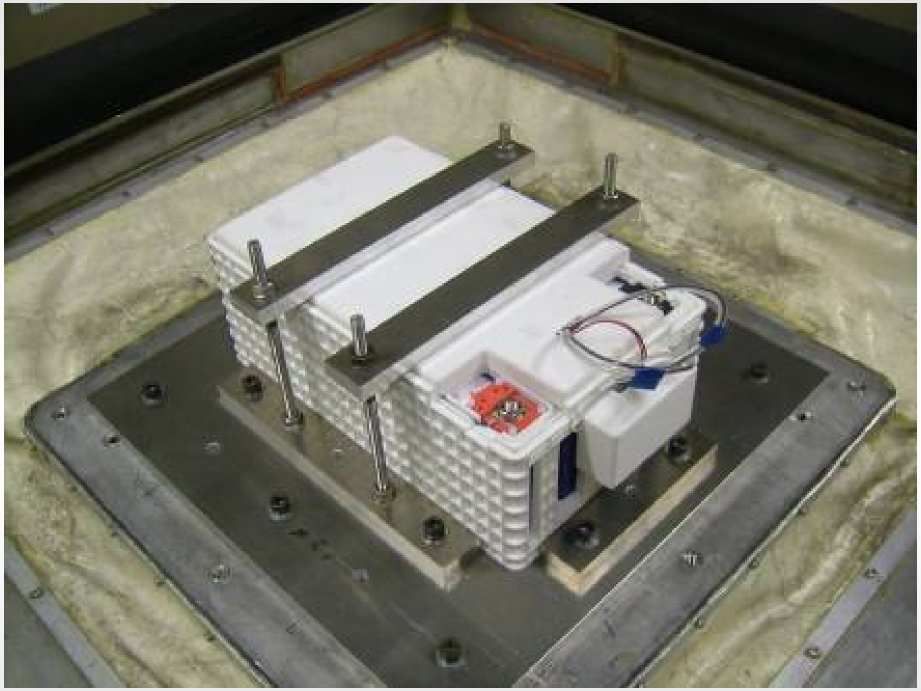
Cooling Air Flow of LIM30H-8R



Battery powered tram
(Railway Technical Research Institute,Japan)-

Cell	**55Ah-class proto type**
	(92W, 170L, 133H)
Battery system	**168 cell-series**

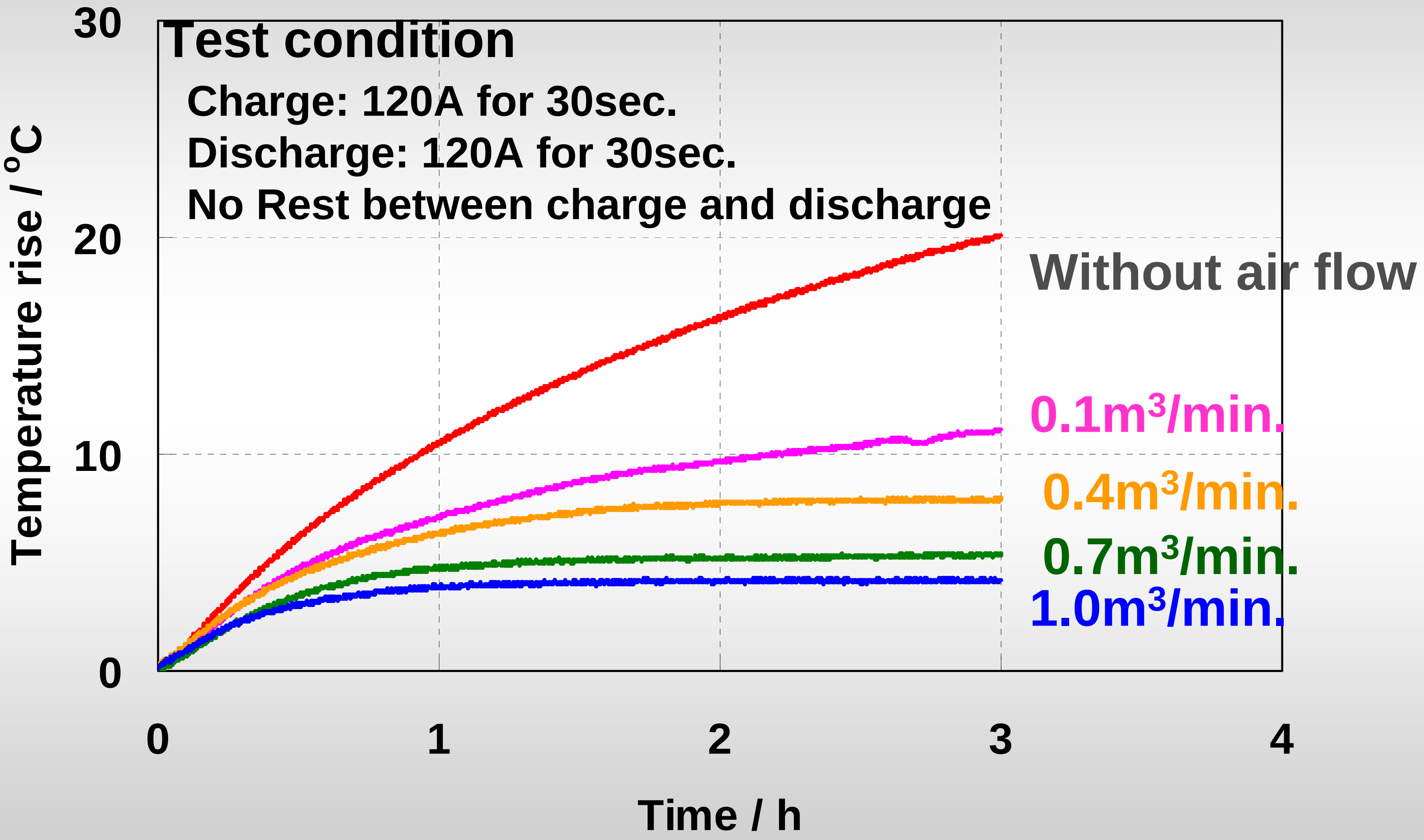
LIM30-8
Environmental Test



Vibration test

- UN3090
- JIS E 4031 2B (JIS : Japanese Industrial Standard)

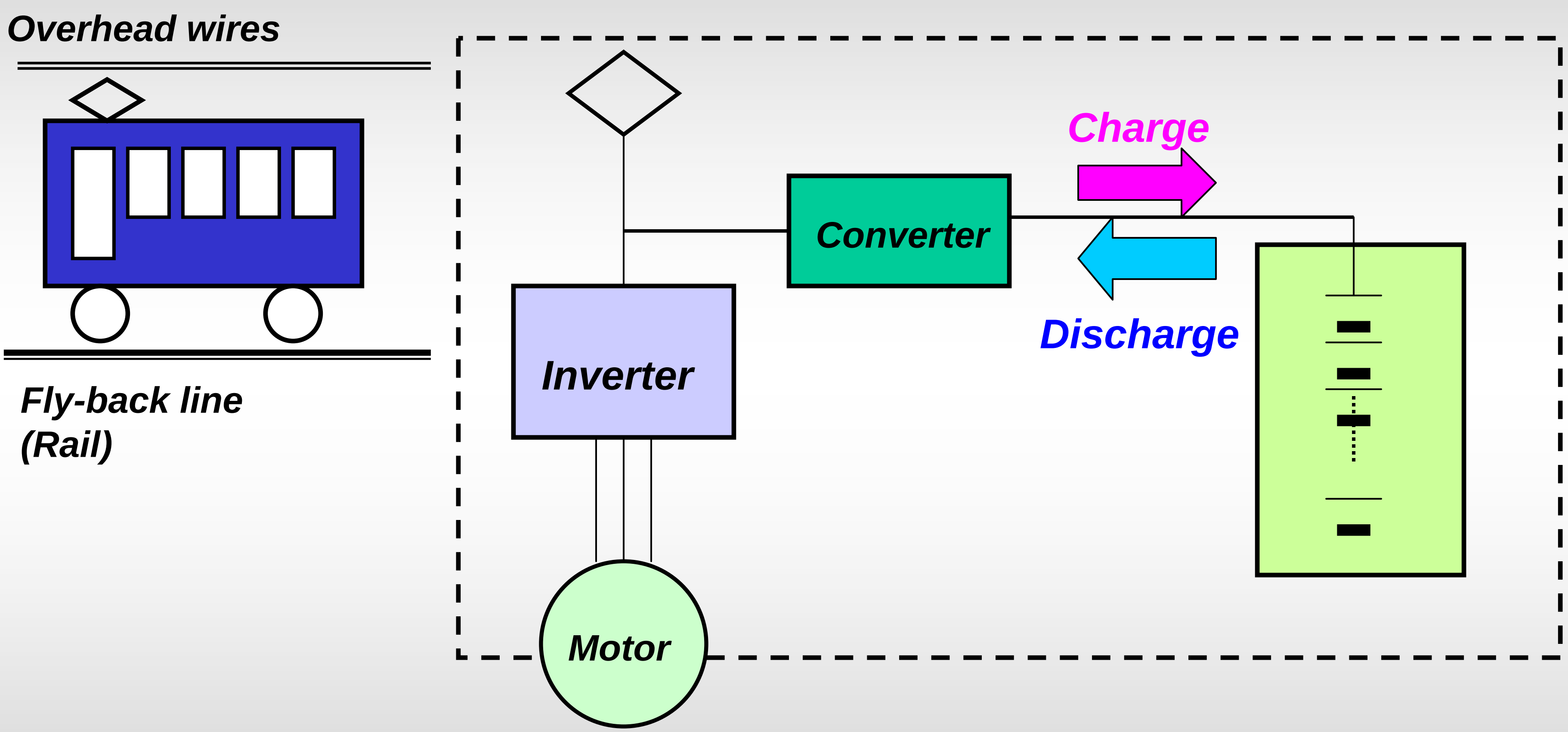
Temperature Rise of LIM30H-8R with Large Current (120A) Operation with Various Air Flow



Agenda

- Cell Specifications, Technologies and Performance
- Battery Module Specifications and Cooling Evaluation
- Evaluation of Energy Efficiency for Hybrid Powered Energy System (Railway Vehicle Systems)

Example of Hybrid Powered Energy System (Hybrid Railway Vehicle Power System)



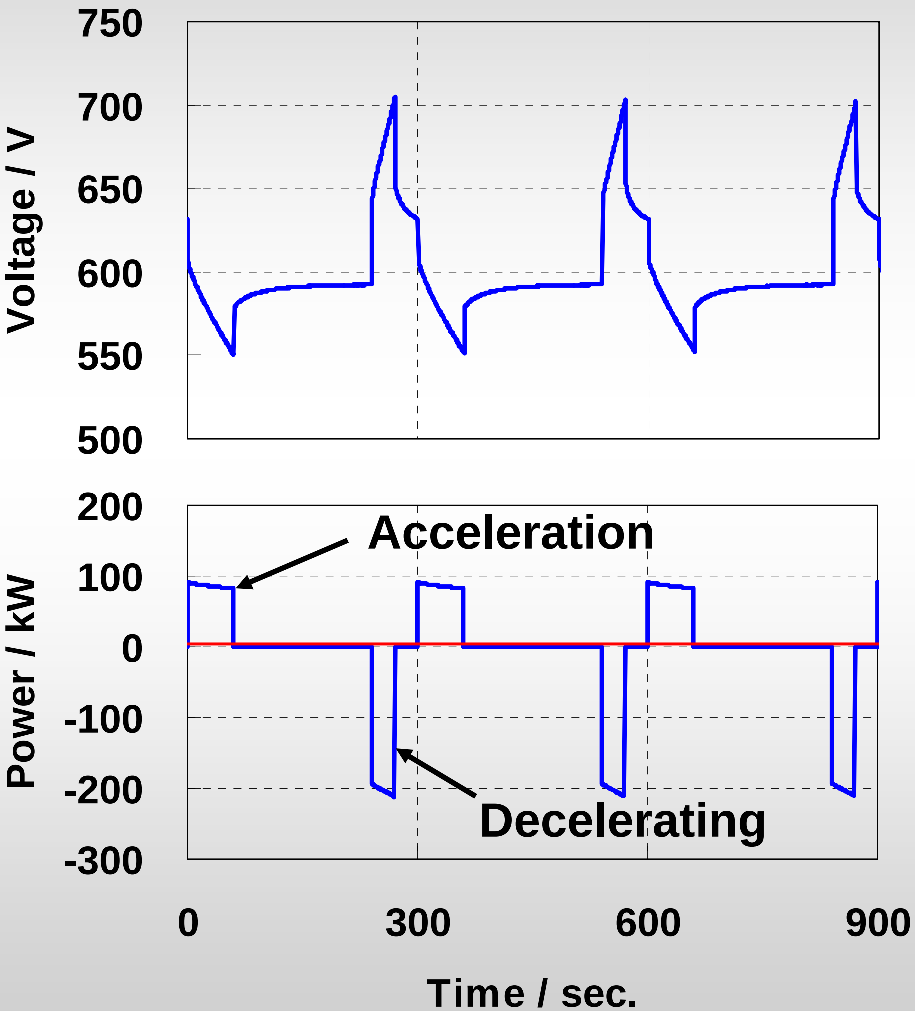
Evaluation of Energy Efficiency for Hybrid Railway Vehicle Power System

Test Battery: LIM30H-8R-22series (30Ah-634V)

Charge discharge conditions:

1. **Discharge** (Acceleration assist): **90kW for 60 sec.**
2. **Rest** (Constant speed running): **180 sec.**
3. **Charge** (Regeneration at Decelerating): **200kW for 30 sec.**
4. **Rest** (Stop at the station): **30 sec.**

Result of Energy Efficiency Test for Hybrid Railway Vehicle Power System



Energy efficiency

$$= \int W_{out} dt / \int W_{in} dt$$

= 82%

Conclusions

Newly developed Large-sized Li-ion Battery Module(LIM30H-8R) for Hybrid Powered Energy System has the following features:

- **High rate charge and discharge capability**
- **Longer life performance under large current charge discharge pulse cycles**
- **CS (cell scanner) is included in each battery module, Battery Monitor communicates to vehicle**
- **Thermal management for large current continuous operation**
- **Higher energy efficiency suitable for hybrid energy system**

Contact Information

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- SALES Contact:
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Power-Managed HMMWV Demonstrator

Joint Service Power Expo
April 25, 2007

Problem statement

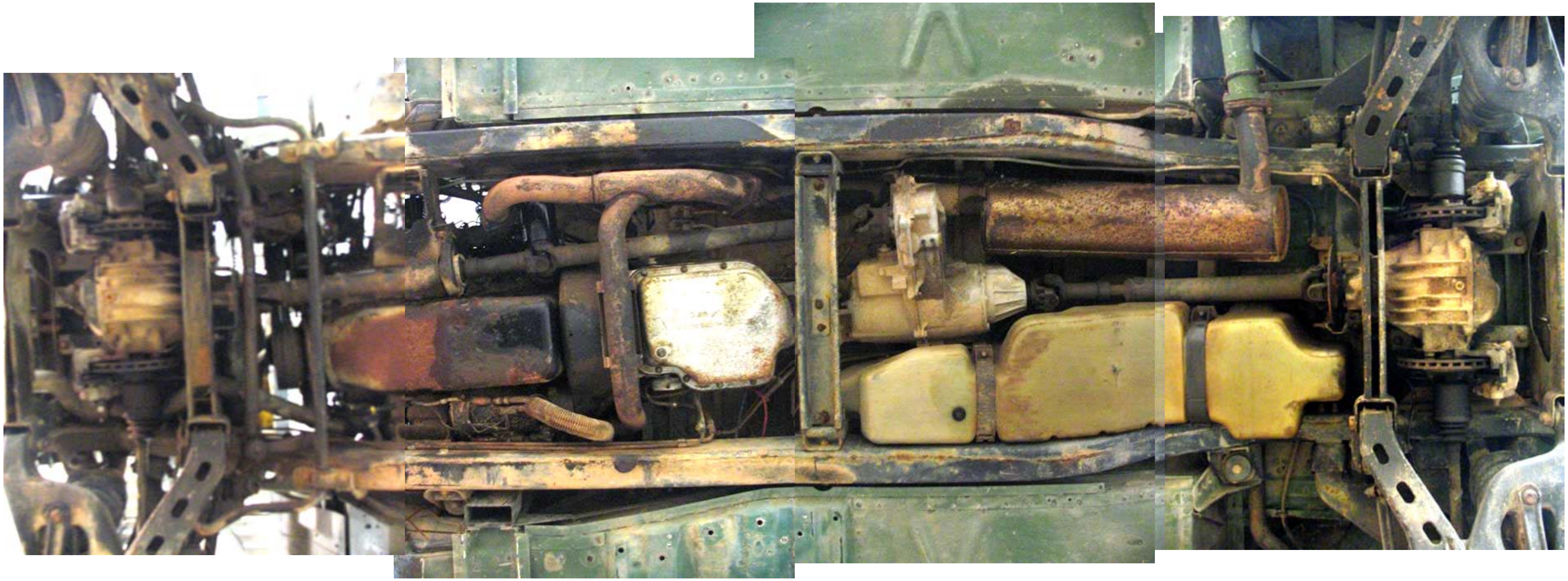
- There is an urgent theater requirement for a self protection and IED defeat suite of subsystems on tactical wheeled vehicles (TWVs)
- HMMWV and EOD armored trucks (i.e. Buffalo, Cougar, RG31, etc.) do not have enough electrical power for this equipment
- The immediate power requirement is for 28VDC… 400 amps across the entire engine operating range
  - ONR/USMC OBVP program is developing AC export power
  - 115/230VAC is a *future* requirement for IED defeat
- DoD is seeking alternatives

Urgent Warfighter need

HMMWV integration considerations

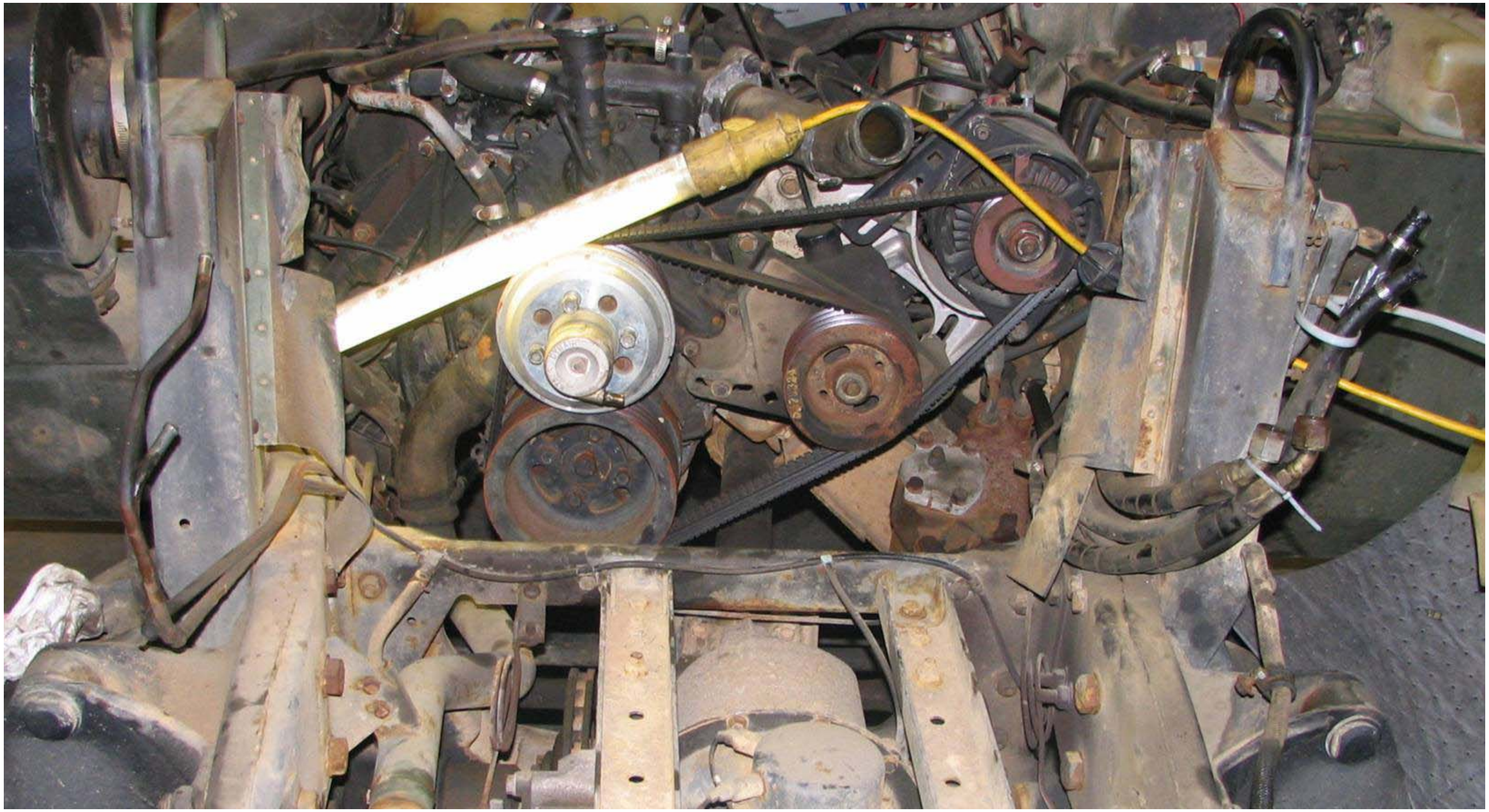
BAE SYSTEMS

HMMWV chassis packaging

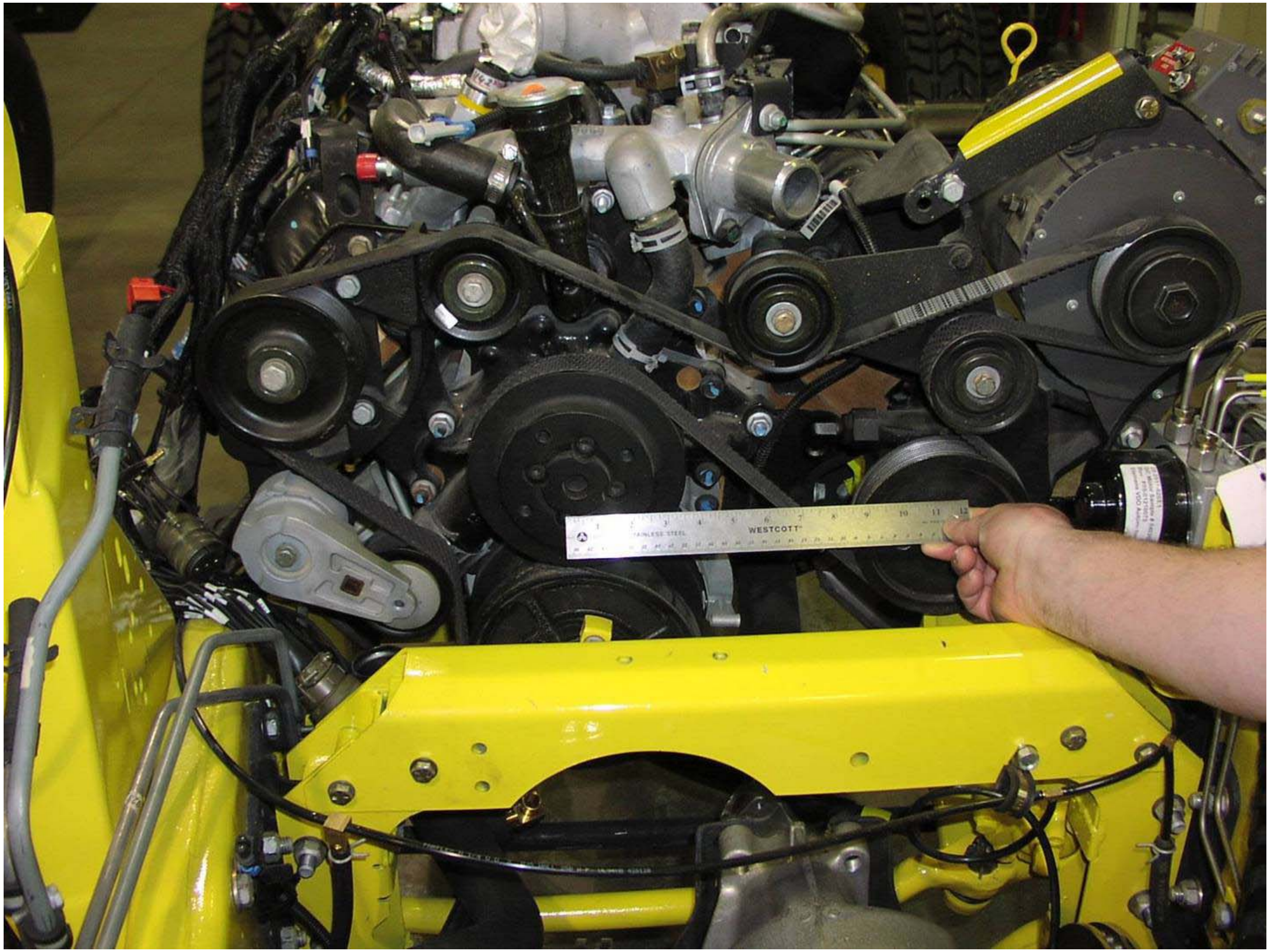


No space claim available under the chassis

HMMWV engine with v-belts (old 6.2L)



HMMWV engine with serpentine belt (new 6.5L)

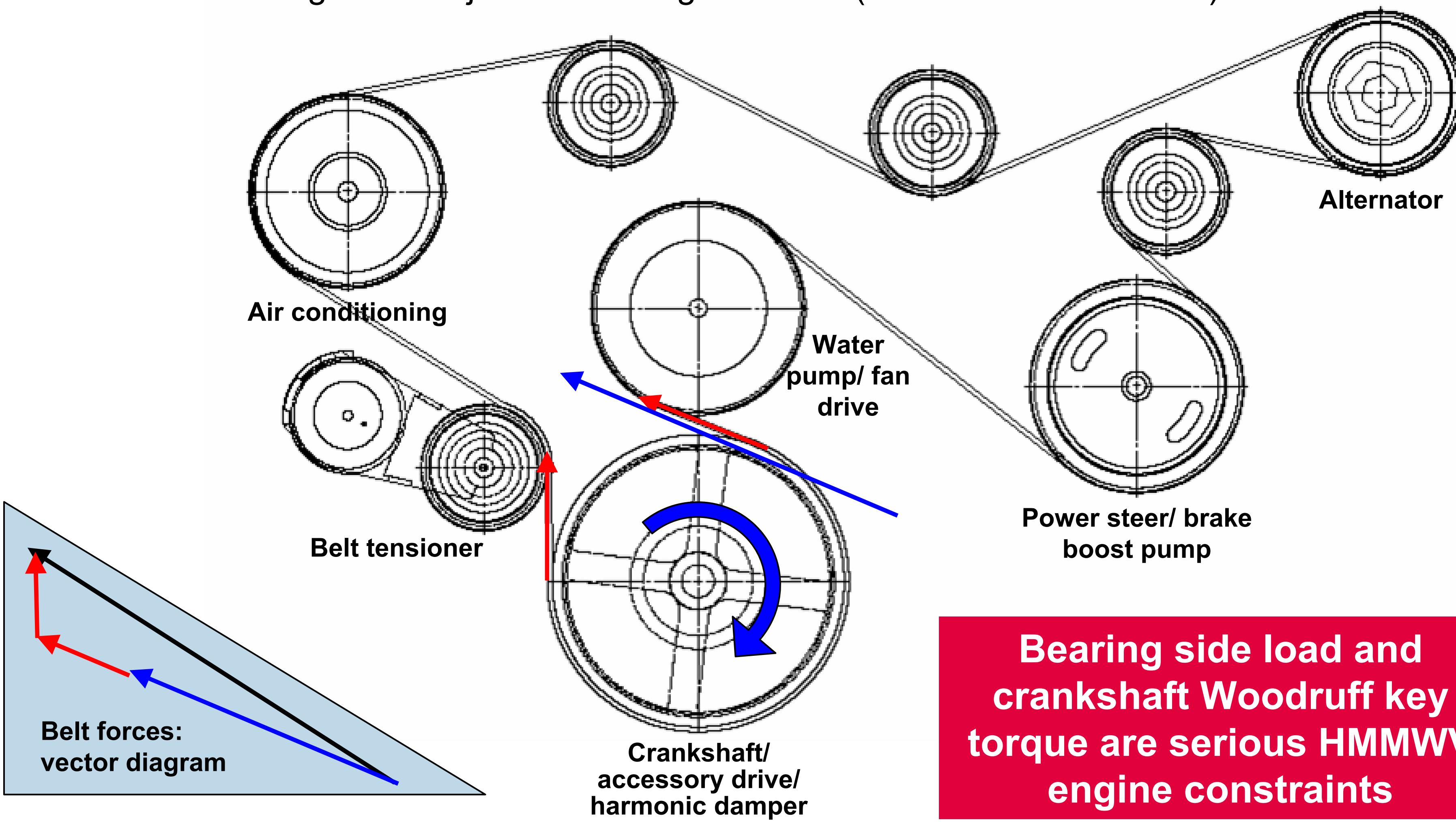


A) Static belt tension force vector

B) Pulley torque force vector (acts on crankshaft key)

C) Pulley torque reaction force (due to sum of all mechanical loads)

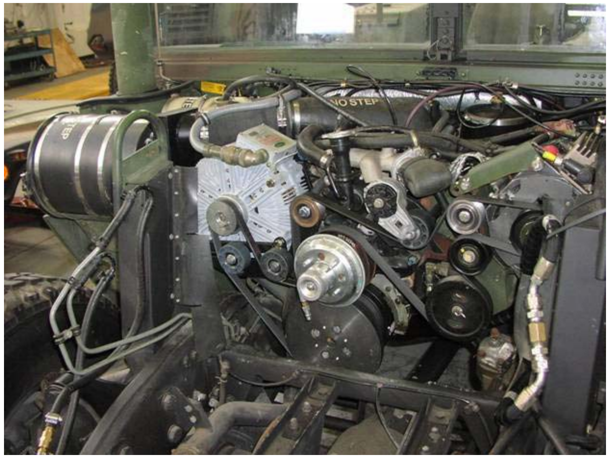
Engine main journal bearing side load (vector sum of A and C)



Bearing side load and crankshaft Woodruff key torque are serious HMMWV engine constraints

Potential solutions

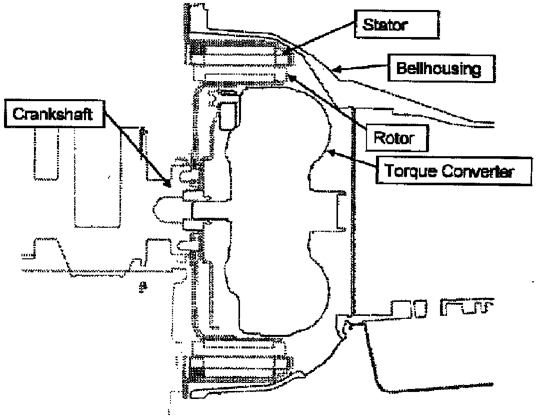
Dual belt driven HV generator



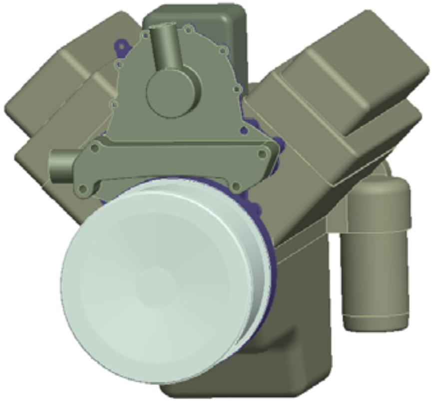
Alternator + belt driven HV generator

Turbo alternator

Conventional 28VDC alternators



Flywheel ISG



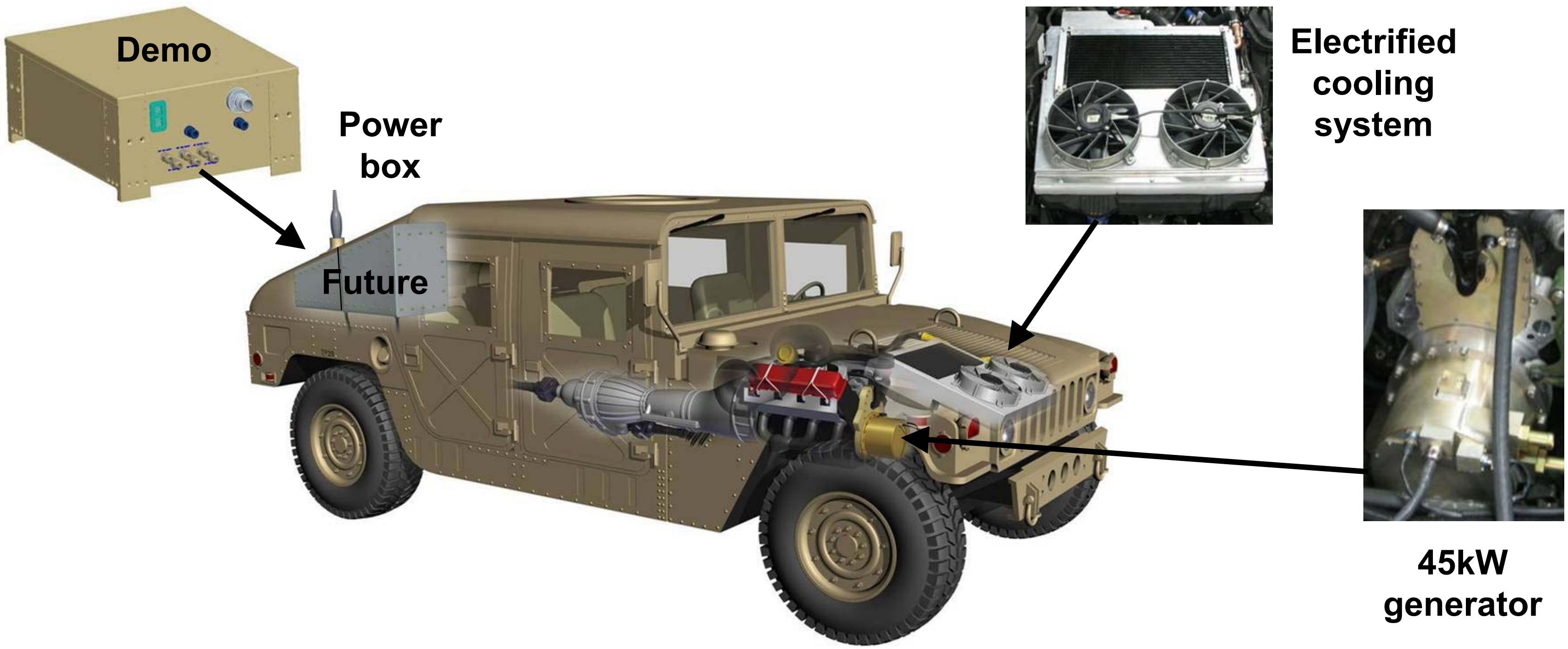
Front crank mount ISG

Solution comparison

- Single and dual belt driven high voltage generators
  - + COTS solution, easy to install, low cost
  - − Won’t make full 400 amps 28VDC at idle, belt drive issues
- Turbo alternator
  - + Small, lightweight, easy to install
  - − Will not make power at idle, high risk approach
- Conventional 28VDC alternators
  - + Easy to install, low cost, mature technology
  - − Won’t make full 400 amps 28VDC at idle, belt drive issues, inefficient
- Flywheel integrated starter generator (ISG)
  - + Ideal solution for new vehicle designs
  - − Retrofit intrusive, requires transmission and torque converter removal / mod
- Front crank mount ISG
  - + Will make 400 amps 28VDC at idle, field retrofittable, efficient, robust
  - − Retrofit more complex than belt drive approaches

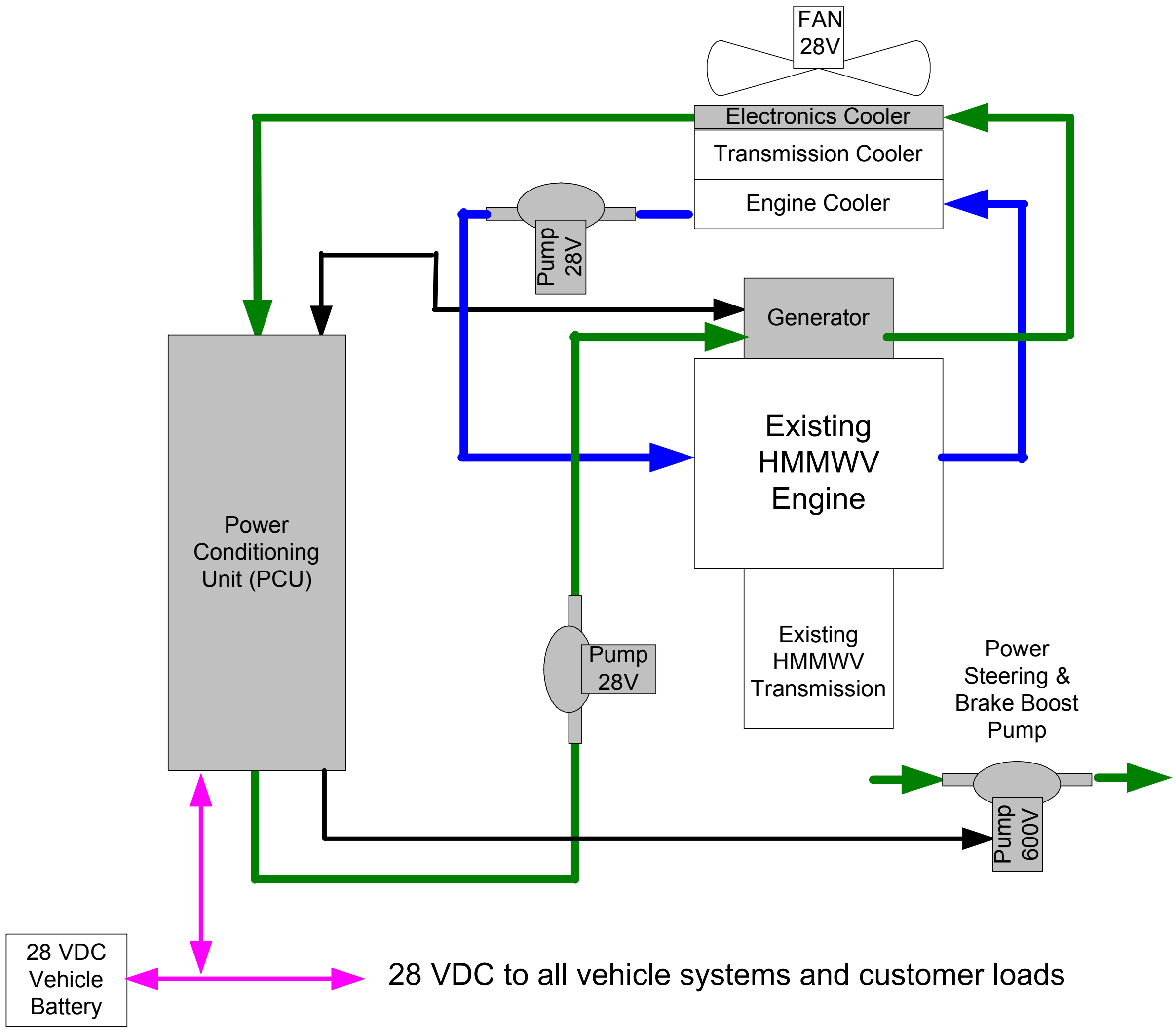
Front crank mount integrated starter generator (ISG) w/ electric accessories
Power-managed HMMWV

Power-managed HMMWV overview

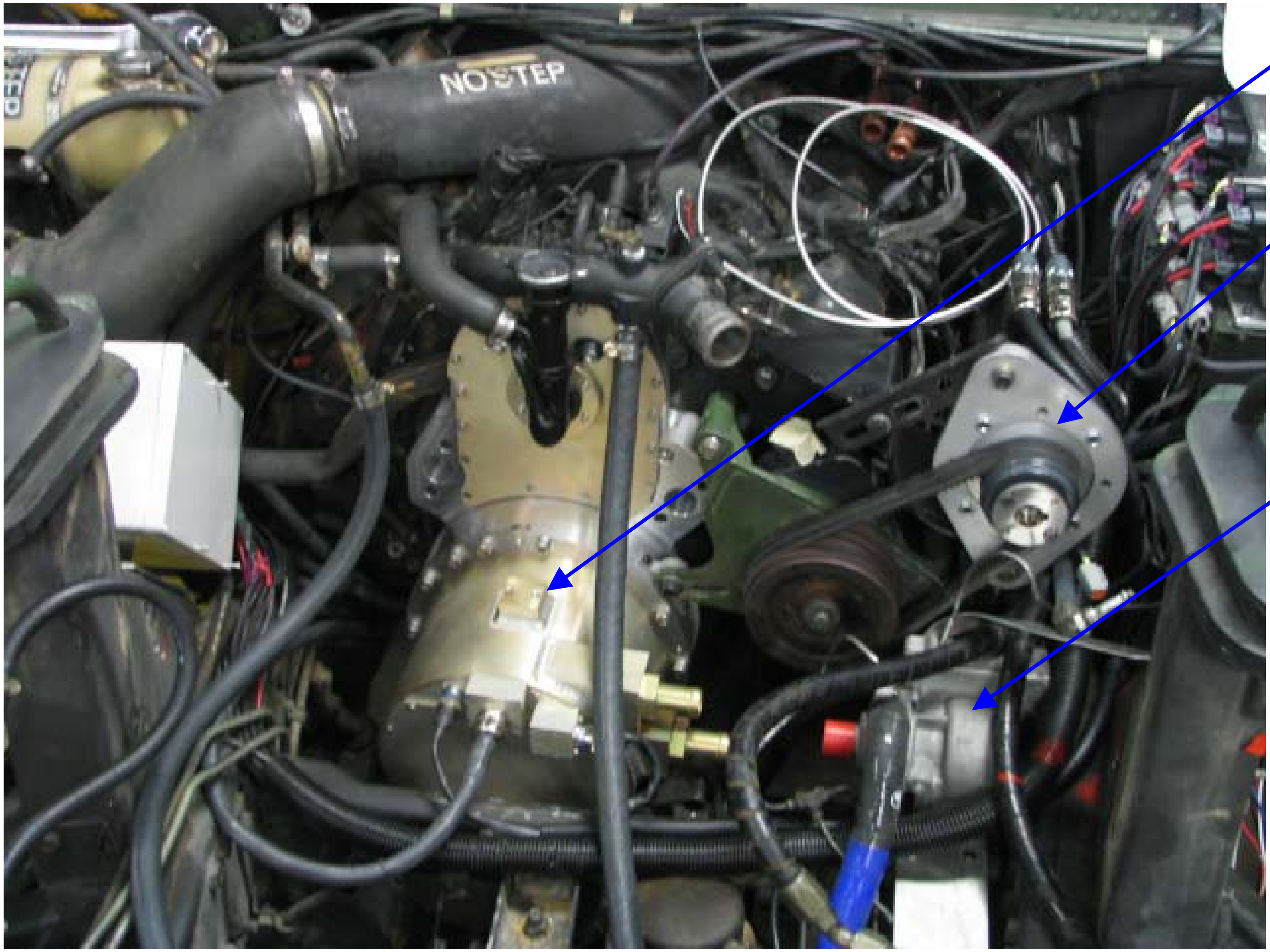


- Provides 400 amps of 28VDC power (11.2kW) over the entire engine operating range
- Provides 1kW 115VAC power (expandable to 30kW 230VAC power)
- Generator installs directly on engine crankshaft for high reliability and high power capability
- Automotive accessories are electrified for high efficiency and superior health monitoring
- Cooling system is electrified for superior engine cooling performance, even at low speeds

System architecture



Engine dress



ISG mounted on HMMWV engine crankshaft

Electric motor powering existing power steer pump

Generator and electronics cooling pump

HMMWV cooler stack removed for clarity

Cooler stack and electric accessories installation

Engine fan controllers (4)

Electronics and generator Cooler

Main cooling fans (two of 4)

Engine radiators

Engine water pump and controller

All engine accessories are power-managed

BAE SYSTEMS

Demonstrator status

- Vehicle build complete
- 400 Amp power delivery and electric accessory functions verified
- Final integration and road testing in process
- Will be available for targeted customer demonstrations in May 2007

Summary

- Satisfies urgent theater requirement for vehicle power
- Provides 400 amps of 28VDC over the entire engine operating range
- 30kW of clean 230VAC power may be added (as an option)
- May be installed in the field
- Space claim is compatible with HMMWV
- Will work on transmission PTO (for armored trucks)
- Improves HMMWV fuel consumption and system reliability
- Enhances HMMWV cooling system performance
- Flexible common modular power system (CMPS) architecture leverages FCS and ground combat vehicle developments